(2)

AN EXPLORATION OF ISSUES RELATED TO FUTURE SPACE LOGISTICIANS

THESIS

Stewart G. Carr
Captain, USAF

AFIT/GLM/LSM/89S-6

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY
Wright-Patterson Air Force Base, Ohio

AFIT/GLM/LSM/89S-6

2

AN EXPLORATION OF
ISSUES RELATED TO
FUTURE SPACE LOGISTICIANS

THESIS

Stewart G. Carr
Captain, USAF

AFIT/GLM/LSM/89S-6

The contents of the document are technically accurate, and no sensitive items, detrimental ideas, or deleterious information is contained therein. Furthermore, the views expressed in the document are those of the author and do not necessarily reflect the views of the School of Systems and Logistics, the Air University, the United States Air Force, or the Department of Defense.

AFIT/GLM/LSM/89S-6

AN EXPLORATION OF
ISSUES RELATED TO
FUTURE SPACE LOGISTICIANS

THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Logistics Management

Stewart G. Carr, B.S.

Captai USAF

September 1989

Approved for public release; distribution unlimited

Preface

The purpose of this study was to explore issues related to space logistician development. The future space systems of the Air Force will require highly trained and dedicated logisticians to support them. The Air Force needs to start now if we are to develop a qualified cadre of logisticians for space systems.

This thesis was originally intended to develop a "model" of the Air Force space logistician, determine the qualifications and skills required, and determine what, if anything, the Air Force needs to do to develop space logisticians. However, the focus of this research shifted to that of exploring issues because of weaknesses in the methodology required for the original purpose. This research is still meaningful however, since it provides a starting point for further research in the area.

In performing this research I have had a great deal of help from others. I am deeply indebted to my short notice advisor, Capt Carl Davis, who during the last month of this research went from a reader to a full advisor. Without his guidance, I wonder if this research would have been completed on time. I would also like to thank the experts that participated in my Delphi group. Although they must remain anonymous, I learned a lot through talking with them. Finally, I wish to thank my daughter Erin for her attempts at patience, and not really understanding why daddy couldn't play as much as he used to. She can now have her daddy back.

Stewart G. Carr

Table of Contents

List of Figures

List of Tables

AFIT/GLM/LSM/89S-6

Abstract

The purpose of this research was to explore the space logistics arena for issues related to space logistician development, that require further research. The study specifically looked at qualifications, training, maintenance, and future requirements to determine areas that may require advanced preparation in the development of future logisticians.

The study found that there are no specific qualifications peculiar to space logistics. Experience and an understanding of the space environment were seen as the most desirable qualities. However, the personnel system does not allow the space logistician to gain enough experience before they are moved, and the lack of training for new space logisticians severely hampers their usefulness.

The future requirements for space logisticians is increasing. The Air Force role in space is projected to increase significantly over the next decade and a space logistics infrastructure needs to be developed now if the Air Force is to meet its own needs. Such issues as organic launch capability and on-orbit maintenance and support are serious future requirements for the Air Force.

This study found ten such issues that require further refinement before the findings of this research can be generalized outside the bounds of this thesis. Care should be taken to ensure these findings are not misguided.

AN EXPLORATION OF
ISSUES RELATED TO
FUTURE SPACE LOGISTICIANS

I. Introduction

Overview

America returned to space in September 1988, almost three years after the Challenger disaster. The launch of the space shuttle Discovery restated America's commitment to manned space flight and reemphasized the National Space Policy, ". . . to the exploration and use of space by all nations for peaceful purposes and for the benefit of mankind" (1:7).

The return of the space shuttle also began the process of putting America back on the road to meeting its long term space objectives, which include a manned space station, the space telescope, and the Strategic Defense Initiative. However, if these objectives are to be met, logistics support must be a key factor in the planning.

This chapter begins by introducing the basic issues and background of the research topic by describing the specific problem. The research objectives, the research questions, as well as the scope and limitations of the study are also presented.

General Issue and Background

Logistics is constantly changing with improving technologies. The area of space logistics is no exception and is probably the most dynamic of the logistics areas. As space technology continues to improve, logisticians must keep pace in order to provide adequate support of current and future systems.

Although standard logistics principles apply, space logistics presents unique requirements that involve new terminology and analytic tools required to refine the application of these principles (30:30). The unique requirements of space logistics are not new. The United States Army Quartermaster Corps recognized as early as 1960 that support of space systems was of critical importance and proposed that NASA develop a Supply Support System for space operations (18:339). Many of the proposals of the Quartermaster Corps are just as viable today as they were almost 30 years ago.

> The importance of starting early on a program of research and development to address space logistics problems to avoid 'wasteful, duplicative crash programs when it is almost too late to accomplish the objective'. (18:339)

Space logistics was again recognized in 1966 by Werhner von Braun, at the "First Annual Logistics Management Symposium." Then "Dean" of the United States Space Program, von Braun welcomed the newly incorporated Society of Logistics Engineers (SOLE) as a "much needed professional and educational organization" (24:48).

The concepts of reusable spacecraft was discussed during the 1960's as well and, with the advent of the Space Transportation System, has been successfully demonstrated. NASA, during the development of the shuttle, defined and acquired hardware and logistical capabilities to support the system (11:23). At the same time the Air Force was aggressively working on their own shuttle launch facility at Vandenberg AFB, Ca. This raised new logistics challenges for NASA and the Air Force. Supporting two launch complexes on opposite sides of the country was going to be no small task. This second complex at Vandenberg AFB has subsequently been mothballed for possible future use. However, challenges posed during the development of the shuttle complex provided new ideas for logisticians (11:23-25).

The United States has already demonstrated logistics maintenance actions in space with the retrieval of the Westar and Palapa satellites, and on-orbit repair of the Solar Max Mission and Leasat satellites in 1984 (2:13). Minor variations in the specifications of the Solar Max and Palapa-Westar prevented easy recovery of these satellites (28:40). The sheer ingenuity of NASA made the recovery possible. Had integrated logistics support (ILS) concepts been incorporated in the acquisition of these satellites, standardization in specifications and pretested support equipment required to recover them would have been available prior to the mission.

The Air Force is taking steps to prepare for logistical support of space systems. In 1987, the PACER FRONTIER program was born. This innovative program is the result of cooperation by Air Force Systems Command (AFSC), Air Force Space Command (AFSPACECOM), and Air Force Logistics Command (AFLC) to improve the support of space and early warning systems. PACER FRONTIER is a detachment of Sacramento Air Logistics Center (SM-ALC) and is located at Peterson AFB, Colorado. Its primary strategy is to centralize, consolidate, and collocate the system management and technical support structure for space and early warning systems with the operational user (20:1.2-1.7). Although, this is a large step toward logistics support of space systems, the PACER FRONTIER program is concerned primarily with only one segment of space operations, the user segment.

In order to fully understand and support space operations, all four segments must be taken into consideration. These four segment are; the launch segment, the space segment, the control segment, and the user segment. The launch segment inserts spacecraft into orbit or elsewhere in the space medium; the space segment includes on-orbit operations and servicing; the control segment monitors spacecraft health and directs operations; the user segment operationally interacts with the space segment to give utility to operations (2:12). Integration of these four segments, with the elements of ILS is the key to successfully supporting space systems.

Research in the area of developing logisticians has focused primarily on senior logisticians. Over the last several years research projects at AFIT have developed models of the characteristics, qualities, and background requirements for senior military and civilian logisticians. These research efforts are summarized in Chapter II and will be used as a foundation for this research effort.

Justification

As the capabilities of tne space shuttle increase and new systems such as the space station, new heavy lift boosters, Orbital Maneuvering Vehicle/Orbital Transfer Vehicle, and the National Aerospace Plane continue development, logisticians must be prepared to support them. The Air Force will be directly involved in these efforts and must develop logisticians at lower levels, familiar with the complexities involved, to properly support space systems.

Research Objectives

The overall objective of this research is to explore the space logistics arena for topics related to space logistician development, that require further research. Specifics, such as qualifications, training, maintenance, and future requirements, will be researched to determine specific areas that may require advanced preparation in the development of our future logisticians.

Research Questions

To meet the research objectives, answers to the following questions will be researched:

1. What skills and qualifications are required of space logisticians? Are they significantly different from logisticians in general?

2. What are the future requirements for the space logistics field?

3. Are we adequately preparing people to assume duties in space logistics? What gap exists in developing these individuals? Are we adequately prepared for long-term needs of space logistics?

Scope and Limitation

Although the need for qualified space logisticians is not restricted to the Air Force, this research is limited to Air Force requirements.

The subject area of this research is qualitative rather than quantitative. Therefore, the sample population was not randomly selected, rather it was purposefully chosen by the researcher to obtain the most expert judgement possible. This study is exploratory in nature. It utilizes the results of three interviews and six experts in a Delphi study as a first step in the process of determining what qualifications are needed in a space logistician, their perceptions of future requirements and their opinions as to current training. Care should be taken not to generalize these results beyond the bounds of this thesis. The researcher's intent was to identify potential issues and general trends only. Appendix A contains definitions of key words and phrases used throughout this thesis.

II. Literature Review

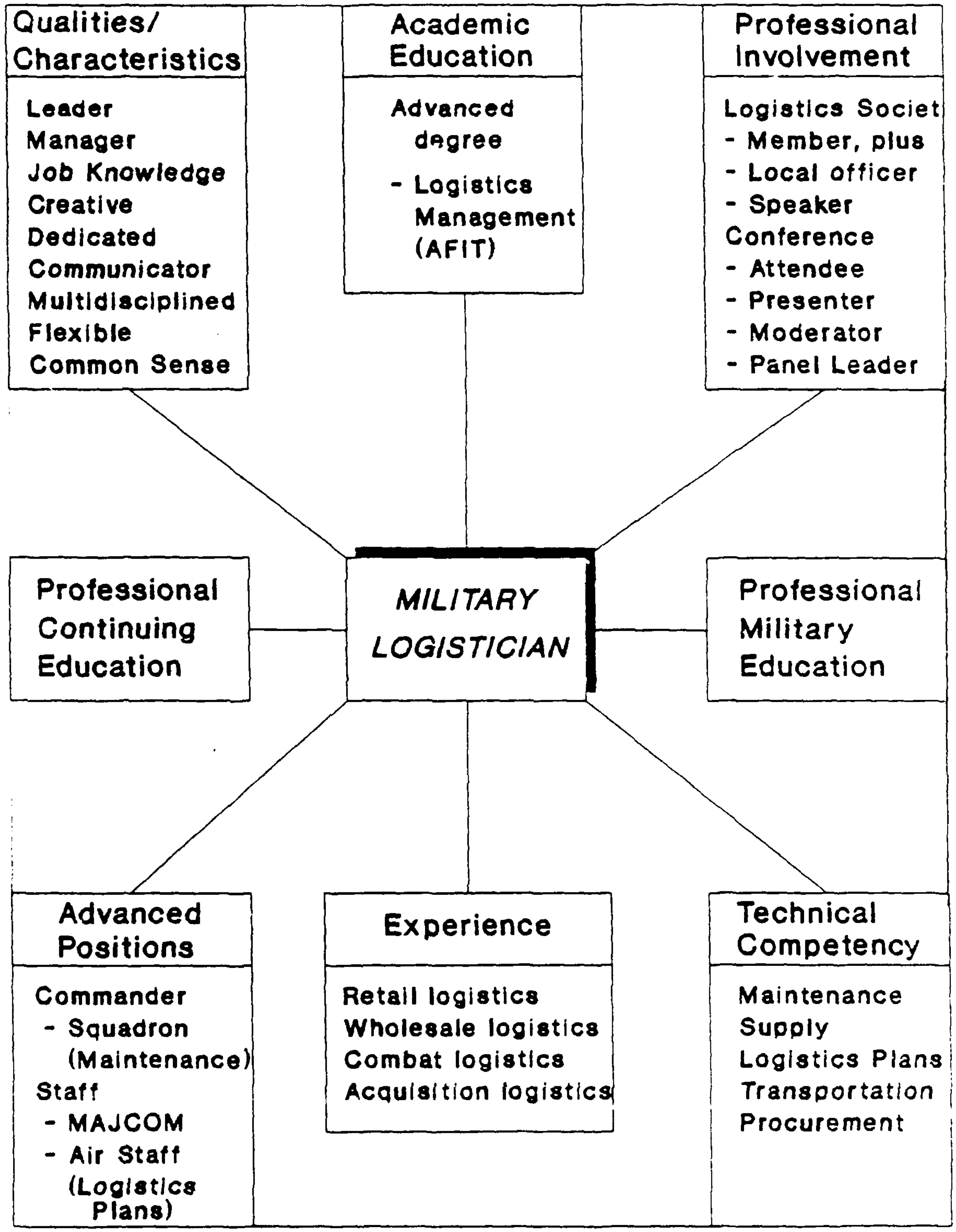
This review of the literature is intended to provide the reader with an overview of research pertinent to the subject of space logisticians. The review focuses primarily on the area of space logistics; however, to provide a framework for the study, an update of current research in the area of logistics career development is necessary.

The review begins with a synopsis of research conducted at the Air Force Institute of Technology (AFIT) over the last four years concerning the development of a career guidance for senior logisticians. Finally, research and literature in the area of space logistics is summarized.

Senior Logisticians

Over the last four years, five research projects have been undertaken at AFIT to determine a model of what qualities, characteristics, and background requirements senior logisticians should possess. In 1985, Captain Allan Overbey developed what has become known as the "AFIT model" for senior military logisticians. He identified the Air Force shortfall of selecting and developing senior logisticians and his research focused on determining what special characteristics and background senior military logisticians should possess to prepare them for managing logistics systems (19:6). Overbey, because of the lack of data pertinent to his study, selected a group of logistics experts and through the use of interviews and a Delphi survey, built a model of the qualities, characteristics, and background requirements for senior military logisticians (19:56). Overbey's model is presented in Figure 1. His conclusions include the following recommendations; (1) establish an undergraduate logistics program at the Air Force Academy, (2) establish an executive PCE course for Directors of Logistics, (3) screen and groom logistics candidates that show potential for increased logistics responsibilities, and (4) establish specific criteria for Director of Logistics positions and an appropriate career development model including: an advanced degree in logistics management; experience in at least two logistics areas; command experience in logistics; and staff experience (MAJCOM, Air Staff) in logistics (19:134-135).

Overbey's model became the foundation for four other studies during the next four years. Two follow-on studies were conducted in 1986 by Captain Adelle Zavada and Captain Frank Gorman. Zavada wanted to determine how well Air Force colonels fit Overbey's model of senior military logisticians and determine what the acceptance level of the model was in the field (32:5). She developed a weightings scale for Overbey's model to compare current senior military logisticians to the model. To collect her data, Zavada employed a mail survey designed to correspond to the three major dimensions of Overbey's model: experience, education and training, and professional attributes.



(13:17)

Figure 1. Overbey's Model

Zavada concluded that, "As a group, senior officers currently serving in the logistics career fields do not 'fit' Overbey's model to a high degree" (32:104). She found that officers who had spent the majority of their careers in logistics had a better 'fit' than non-career logisticians, with experience the key discriminator. However, she did conclude that the model was a valid representation of the essential qualities, characteristics, and background requirements of the professional military logistician. And as such, is a practical and realistic approach to logistics career development (32:131).

Also, in 1986 Captain Frank Gorman conducted research to develop a career development model for senior logisticians. Although his research is similar to Overbey's, he took a systems perspective of developing logisticians that could manage the total logistics system (10:4). Gorman's model, although structured differently, contains many of the same elements as Overbey's. Gorman constructed his model based on published research studies, expert opinion expressed in the literature, and his own synthesis of the research studies and expert opinion (10:54). He then validated the model by constructing a survey to determine if it was "acceptable to logisticians who were both knowledgeable of the current logistics career fields and who would be willing to participate in the model, if implemented" (10:55). He concluded that not all of his model elements were validated. The key elements of his model that were validated include: logisticians need a systems perspective, experience and training in interpersonal skills and communication, flexible career development, instruction in logistics systems during initial training, and logisticians should be specialists early in their career progressing toward generalists with increasing rank (10:176-190). He recommends that logisticians increase communication and interpersonal skills, improving their systems perspective, improve supervisor involvement, and develop an executive development program for senior logisticians (10:188-190).

In 1987, Mr. Donald Nancarrow attempted to apply Overbey's model to senior civilian logisticians. His objectives were essentially the same as those of Overbey in developing a model for senior military logisticians and of Zavada in weighting Overbey's model. Because of a time problem, Nancarrow was unable to develop a civilian model. However, he concluded that Overbey's military model was applicable to civilian logisticians with no significant differences. Nancarrow recommended that follow-on research be conducted to develop a normative model for civilian logisticians with additional elements for academic education and general skills, and that the Air Force continue and extend career development for civilian logisticians (17:157-158).

Follow-on research of Nancarrow was conducted in 1988 by Captain Ralinda Gregor. Gregor based her research on Overbey's model and on the foundation built by Nancarrow. To meet the objectives of her study, Gregor used a Delphi survey to solicit opinions from 30 expert senior logisticians. The data gathered helped her construct a model of the ideal requirements for senior civilian logisticians (13:43). Gregor then selected a group of expert logisticians to weight the model. She then rank ordered the component, the categories in the components, and the elements of each category to determine what experts believed to be the best model for civilian logisticians (13:43-44). Gregor randomly selected a group of senior civilian logisticians to determine how well they 'fit' the model. Her survey results indicate that, on the average, the senior civilian logistician did not meet the criteria of the model very well. However, the model does provide relevant career guidance to civilian logisticians (13:x).

The three models presented, offer a different persp-ective of the logistics career field, but one underlying theme is the need for additional training in logistics courses. Also, the research indicates that logisticians should be generalist at the managerial levels. Gorman takes this idea one step further and found that logisticians felt they "should be specialists initially and a generalist later . . . that major was the transition rank from specialist to generalist" (10:182).

Space Logistics

Literature in the space logistics area is concerned mostly with specific details of space operations. Primarily, the articles and studies discuss what systems should be deployed and possible maintenance concepts for the specific system. "Historically, maintenance in space was accomplished on the ground and all launches were one-shot affairs" (28:39). This one-shot attitude did produce extremely reliable space systems because of the high cost of replacement. However, as technology progressed, the idea of supporting existing systems caused a rethinking of the "one-shot" attitude. If space logistics is to be successful "four subsystems of logistics" need to be considered: (1) requirements determination, (2) acquisition, (3) distribution system, and (4) maintenance (28:39).

The first, requirements determination, is the use of "analytical and simulation techniques . . . to direct logistics actions for space systems by comparing alternative design and maintenance efforts" (28:39). In previous years difficulties were encountered in determining systems requirements because of the lack of an "accessible data base" (28:39). The difficulty came from the fact that early information was classified or was not available. But, the increasing number of commercial and unclassified satellites has produced a database that is available to logisticians (28:39). Logisticians must utilize this database to produce tools and equipment necessary to support space systems. The database has been used to produce tools and techniques for performing on-orbit maintenance of satellites, but these techniques are still in their infancy. "Although the techniques help determine logistics requirements, acquisition strategies could negate any gains made from directing logistics needs" (28:40).

The acquisitions phase of logistics is important because it provides "standardization and interchangeability" of materials in space systems. "Several satellites that use the same parts provide the key to acquisition" (28:40). The importance of close adherence to integrated logistic support (ILS) would have prevented some of the problems that have occurred in satellite recovery because of minor variations in specifications. "In the acquisition of the satellites, ILS would have provided the technical data and support equipment for recovery" (28:40). In addition, ILS would provide for testing of the support equipment on the ground, before it was actually required for use in space. The development of a logistics support analysis is equally important. Documents similar to Military Standard 1388-1A and 2A ". . . would provide a ready cross reference to interfacing systems" (28:40).

Commercial management practices may also help improve the satellite acquisition process in the Air Force. Even though the space system acquisition process is similar to other acquisition processes.

> Space system acquisition is unique because prototyping and development testing are too costly to be feasible. The acquisition process is therefore modified. The first two phases have the same objectives, but demonstration and validation is limited to studies and component tests. The third phase calls for limited production and deployment in space. If this goes well then follow-on production is allowed. (29:30)

This process does not occur in isolation; however, the interface between the program office and the DOD is extremely important. Four other interfaces are also important to the acquisition process. They are: (1) the program office to user community, (2) the program office to support agencies, (3) the program office to other developers, and (4) the program office to the contractors (29:30).

The first interface, with the user, must be established early because users help structure the top level systems requirements. This interface is extremely significant once testing starts (29:30).

Interface with the support agencies must also be established early because of high support and modification costs downstream. By establishing early interface, support command assessments can be factored into the basic design as well as spares and initial provisioning (29:31).

The third interface is with the development community and serves two purposes. First, it allows the program to go to AFSC laboratories for technology, and manufacturing expertise. Second, it allows for the coordination of design and test between systems that must be operationally integrated (29:31).

The final interface is contractual. There are two important policy features of interest within this interface. First, the contractor and government share the risk for the program. The second policy feature involves social programs. Government contracting is used in part as an instrument of social policy which introduces costs which are not related to the Air Force mission (29:31).

The Air Force acquisition record on space systems to date has been criticized. Six major weaknesses in the process are: (1) Funding Instability, (2) Engineering Instability, (3) Technical Complexity, (4) Multiprogram Interfaces, (5) External Management Interfaces, and (6) Inefficiency (29:48). To help strengthen the space acquisition process, Air Force Systems Command initiated several studies under the title, "Commercial Practices Program" (CPP). These studies examined the Boeing Commercial Aircraft Company, Westinghouse Electric Company, and Hughes Aircraft Company.

These studies offer a "volume of recommendations" that currently are not being implemented by Space Division (29:52). One reason for the recommendations not having been implemented is that they are limited in applicability. The recommendations that are applicable to space system acquisition are contained in a unified list in Table 1. These recommendations "do not provide answers to all of the space acquisition problems but did present some very valuable suggestions" (29:66).

In order to properly cover the final two subsystem, four capabilities must be mentioned. These four capabilities are: the space station, heavy lift booster Orbital Maneuvering Vehicle (OMV)/Orbital Transfer Vehicle (OTV), and National Aerospace Plane (NASP).

Table 1

Integrated List of Commercial Practices Recommendations.

A. ENGINEERING INSTABILITY

1. Derive system need from stratgic planning at AFSC.
2. Use performance specifications vice 'how to' specs.
3. Define test, verification, assurance plans early.
4. Give contractors flexibility to trade cost and performance.
5. Use consultants to help write RFP.
6. Cut program office size and colocate with contractors.

B. TECHNICAL COMPLEXITY

7. Separate high technology from the baseline development.
8. Use preplanned product improvement.
9. Solicit advice (proprietary) from contractors prior to formal contract.
10. Use contractor personnel as government engineering, manufactoring and assurance representatives.
11. Require warranties or use significant on-orbit incentives.
12. Groom government personnel.

C. INEFFICIENCY

13. Use government/contractor data review boards at the start of each acquisition phase.
14. Streamline Cost/Schedule Control Reporting.
15. Maintain development specs only as long as necessary.
16. Be cautious of reference to MIL Specs and Standards.
17. Revise the area of socio-economic contract clauses and reporting.
18. Streamline change processing.
19. Use competitive pricing formulas and consistent escalation clauses.
20. Introduce 'office of the future' concepts into government.

(29:67)

The third subsystem is the distribution system. Current boosters and the space shuttle provide distribution capabilities from earth to orbit. But, these are limited by turnaround time; therefore, the need for "on-orbit sparing of satellites when satellite availability requirements override costs" (28:40) would be necessary. With the limited payload capabilities of the space shuttle, a high payload/low-cost expendable booster will be needed to place satellites in high earth orbit and for large resupply payloads for the space station (2:12). There also exists a problem with reaching satellites in high earth orbit. Vehicles such as an orbital maneuvering vehicle "to either recover . . . or place a technician at the satellite" (28:40) would be required to aid maintenance.

The final subsystem is maintenance. On-orbit maintenance capabilities have already been demonstrated with the repair of the Solar Max satellite. The different techniques that would assist on-orbit maintenance include; paperless technical data, and robotics, to assist technicians performing on-orbit maintenance (28:41).

The uses of a permanently manned space station are virtually endless. Uses such as a space repair depot, satellite servicing center, and a launching pad for high earth orbit would open new horizons for space logistics (2:12). In order to effectively retrieve satellites in high earth orbit OMVs/OTVs will be required to shuttle back and forth between the space station and the satellites. The potential for robotic servicing of these satellites would make this more feasible and cost effective (2:12).

Finally, the NASP would provide a horizontal take off and landing capability, giving the United States immediate access to space. This capability would "also provide low-cost access to orbit and the ability to reach mission critical space assets quickly for rescue missions" (2:12).

Each of these four capabilities are significant to the space program and ". . . effective logistics concepts must be finalized and incorporated before system design proceeds much further" (2:12). Logisticians are faced with a number of challenges in space logistics if this is to occur. First, logisticians must provide for on-orbit logistics. This includes the repair, servicing, and assembly of crafts in space. NASA has already demonstrated some of the capabilities required, such as repair and construction techniques. "As technology and procedures are demonstrated in space, we can expect to eventually service satellites just as we do aircraft" (2:13).

To adequately cover the problems of space logistics, all four segments of space operations must be addressed. "The area of greatest challenge and interest is . . . the spaced-based portion of space systems" (30:30). However, there are a "severe lack of tools to assist in making . . . design decisions that effect supportability and life cycle costs of spaced-based systems" (30:30). Life cycle costing

(LCC) and LSA approaches must be used together in order to maximize component standardization (31:18).

MIL-STD-1388-1A and MIL-STD-1388-2A are normally used for "the analysis process and data processing tool to perform logistics support analysis" (30:30). However, these standards are critically lacking in software supportability factors and data elements, and there are no space peculiar factors (30:31). To determine which factors should be included requires an examination of the peculiar functions of assembly, maintenance, and servicing of space-based systems (30:31). Once these factors are established and quantified, they should be formalized into the current military standards and used to determine support requirements and influence design (30:32). Consideration should also be given to the establishment of separate military standards for space systems to ensure proper and adequate support.

The launch segment includes not only the launch support, "but also the logistics of getting the satellite to the launch pad and the process required to land and turnaround a reusable transportation vehicle" (30:32). The logistics infrastructure for this segment has never been put in place, since launches have been treated as research and development efforts (30:32). For this reason the infrastructure needs to be "normalized" to provide support for the launch segment of space operations.

The third segment that must be considered is the control segment. This segment is the ground based link to the satellite that controls its movement and receives information about the satellites position. "The three main functions of the control segment are telemetry, tracking, and communication" (30:32). These functions perform orbit correction, collision avoidance, and track the satellites location. The factors associated with this segment include the type and period of orbit (30:33). Different orbits require different ground support and possibly more ground stations. The period of the orbit relates to the time it takes for the satellite to complete one orbit. Again, depending on the orbit, repair time may have to be less than one orbital period to effect repairs (30:33).

The final segment addressed is the user segment. "The whole purpose of having our present space system is to provide information to the user" (30:33). The logistics of the user segment is primarily the "number and information requirements of the users, and the time sensitivity of the information" (30:33), and ensuring the standardization of software and hardware to minimize maintenance problems.

These segments cannot be treated individually ". . . when performing logistics analysis" (30:33). They must be incorporated as a whole for proper logistics support of space systems. However, "our record of success in achieving this in normal ground systems is not good" (30:33). Management attention is not sufficient and design tools need to be provided to system engineers so that logistics factors can be incorporated early. This falls back, at least partially, on

MIL-STD-1388-1A and 2A for the lack of a systems perspective for space systems (30:33).

The next challenge facing logisticians is the standardization of components and interfaces. Currently there is no standardization between the DOD, industry, or NASA. This must be corrected before on-orbit logistics can become a reality. A first step in this direction was taken by Space Division when contractors were selected to complete a Space Assembly, Maintenance and Servicing Study (2:13). The primary objective of the study was to identify:

> where on-orbit maintenance and servicing will enhance the system while lowering overall life cycle costs; exploring commonality opportunities among space systems; and consolidating requirements to identify common system performance. (2:13)

If standardization *is to become* reality, incentives need to be provided. Civilian industry is more interested in profits and therefore, not as willing to divulge industrial secrets for the sake of standardization. This leads to sole source contracting and in-turn increased costs to the government (2:13).

The third challenge is that of making repairable versus expendable spacecraft. "This should be determined during satellite design, during which many alternatives are considered and tradeoffs evaluated" (2:13).

Designing to life cycle costs is the fourth challenge. As mentioned earlier LCC is imperative to the success of space logistics. "We must do in space what earthbound logisticians have been demanding for years" (2:14).

The final challenge is integrated logistics support. ILS must be up front during the design not an after thought.

> The principles of integrated logistics support management are as important in planning for space as they are for ground systems - perhaps more so. Incorporating ILS elements such as equipment, transportation, technical data, supply support, and training into space systems is a challenge we face and must deal with today. (2:15)

The Air Force needs more space logisticians. As logistics in space grows, we will need more than the small group of logisticians now available to work acquisitions and support of space systems (2:15).

Summary

It is apparent, from the literature reviewed, that the Air Force will be directly involved in future space systems and therefore, space logistics. The Air Force has already started preparing for space logistics with programs such as PACER FRONTIER. However, more is needed in the areas of experience and training if space logistics is to work. Career development guidelines such as the models developed at AFIT would be a tremendous help toward this goal. Also, logisticians need to work toward standardization of systems, in all four areas of space logistics. Standardization will help "normalize" the logistics infrastructure needed for space systems. Specifics, on development of this thesis are contained in the next chapter.

III. Methodology

The objective of this study was to explore the space logistics arena for topics relating to the future development of space logisticians. The methodological approach used by Overbey in 1985 provides the foundation for this study. A twofold approach of research will be used to achieve the research objectives. Overbey used personal and telephone interviews with logistical experts to build a framework for the Delphi technique. The same approach will apply in this study.

Research Design

To accomplish the objectives of the research, a two phase design is utilized. Phase one, a review of the literature applicable to space logistics, determined where the Air Force currently stands on the issue of space logistics. Phase two involves the development of the data collection instrument, gathering of data, and data analysis to determine the qualifications and requirements of space logisticians. This research design most closely resembles a traditional needs assessment. The first task involves determining the current state of requirements in space logistics. The second task was to understand where the United States in general and the Air Force in particular desires to be in the future with regard to space logistics. With these two polar positions identified, the task of this identification or exploring of issues will lead to future research efforts that will bridge the gap between those "where we are" and "where we desire to be" positions. The remainder of this chapter describes each of these phases in more detail.

Phase One: Literature Review

The literature review is contained in Chapter II of this research. The literature dealing with space logistics was extensive. However, the primary focus of the literature was directed more toward technical requirements of space systems rather than development of space logisticians. This is not to say that the technical requirements of future systems are not important to logisticians. On the contrary, it is vital that logisticians understand what future systems may bring so that they can prepare to support them. Once the technical requirements were identified, it became necessary to determine what qualifications future space logisticians would require to maintain these systems.

Phase Two: Data Collection and Analysis

Population and Sample. The first step toward meeting the objectives of this study was to identify a population from which to sample. Because of the exploratory nature of this study, and the lack of any definable population of space logisticians in the Air Force, pertinent information had to be gathered through the use of expert opinion. Since this study focused specifically on Air Force space logisticians, only experts in the field of space systems were asked to participate. Expert opinion was solicited from the following groups in order to obtain a broad perspective of space logisticians:

1. Senior Air Force logisticians, active duty and retired, and civilian Air Force equivalents, working with space systems.

2. Prominent writers in the field of space logistics.

Individuals were selected based on their current position dealing with space systems, and rank. An attempt was made to use only Lt Colonels and above, and civilian counterparts as the sample of expert military logisticians. This was consistent with the definition of an expert used in prior research. The sample was gathered through discussions with HQ/USAF/LEYE and logistics personnel offices at HQ/AFLC, HQ/AFSC, and HQ/AFSPACECOM. Selected authors, not directly involved with the military, that were encountered during the first phase of this research effort were also asked to participate. A total of 13 individuals were selected to participate in the research. In several cases, two individuals were from the same office. Since this fact could bias the results of the Delphi survey, individuals who were from the same office did not participate in the same area of data collection.

<u>Interviews</u>. Interviews were used in this research effort primarily as a tool for building a base for the Delphi survey. Three individuals were selected for interviews based on their current positions and rank/grade. These individuals

were recommended by HQ/AFLC and HQ/AFSC personnel offices as being knowledgeable in the space logistics arena, but did not meet the criteria of an expert due to rank and experience. The interviews were conducted in two forms: personal and telephone. These techniques are explained in further detail below.

Personal Interviews. One personal interview was conducted with a respondent from Wright-Patterson AFB because of his close proximity to the researcher. The personal interview has many advantages and disadvantages. "The greatest value lies in the depth and detail of information that can be secured" (9:160). Emory gives other advantages including: improved quality of information, more control through prescreening to insure the proper respondent is replying, and the interviewer can make adjustments to the language to clear up ambiguities. Emory says, "the greatest (disadvantage) is that the method is costly, both in money and time" (9:161). Other disadvantages that Emory cites include: reluctance by respondents to talk to strangers, interviewers are reluctant to visit unfamiliar surroundings, and adverse effects can be caused by the interviewer altering questions, or in other ways bias the results. He states three requirements for successful personal interviews: (1) availability of needed information from respondents, (2) an understanding by the respondent of his or her role, and (3) adequate motivation by the respondents to cooperate (9:161).

These requirements were fulfilled by providing the respondent with a brief description of the specific problem being researched and the importance of their participation in the study to ensure maximum participation. An interview schedule containing the specific interview questions for both the personal and telephone interview is contained in Appendix B.

<u>Telephone Interviews</u>. Telephone interviews were used in the same manner as personal interviews in this research. However, the other two interviewees were located at Sacramento Air Logistics Center and; therefore, not accessible for personal interviews. As with personal interviews, telephone interviews have advantages and disadvantages. Emory says, "Of all the advantages of telephone interviewing, probably none ranks higher than its moderate cost" (9:169). Other advantages include time savings, and it is also likely that interviewer bias is reduced. The most obvious limitation to telephone interviews is "that the respondent must be available by phone" (9:170). Limits on the length of the interview is another disadvantage stated by Emory. However, Emory notes this limitation depends on the respondents interest in the topic. Respondents may also find the experience less rewarding than personal interviews. The telephone interview schedule was identical to that of the personal interview, and is contained in Appendix B.

Delphi Technique. "Delphi is the name of a set of procedures for eliciting and refining the opinions of a group of people" (5:1). The Delphi procedures were first advanced by the RAND Corporation in the late 1940s as a means of eliminating the problems related to face-to-face contact. It is a qualitative technique that relies on the judgment and intuition of individuals to arrive at a group consensus in an area of study where knowledge is imprecise (21:173-182).

Dalkey reported three distinctive characteristics of Delphi. They are: (1) anonymity, (2) controlled feedback, and (3) statistical group response (6:3).

Anonymity is a way to reduce the effect of a dominant individual on the group. Controlled feedback reduces irrelevant or biased communications from interfering with group effectiveness. Finally, statistical group response reduces the pressure for a consensus of opinion by ensuring that each member is represented in the final response (6:3).

The first step in the Delphi method is the selection of a panel of experts. This can be a difficult problem because the term 'expert' can have different meanings such "as his status among his peers, by his years of professional experience, by his own self-appraisal of relative competence in different areas of inquiry, by the amount of relevant information to which he has access or by some combination of objective indices and a priori judgment factors" (3:4). In a Delphi study on group effectiveness, Dalkey found that the group error rate decreased exponentially and group reliability increased as the group size increased (7:6-14). Small groups are recommended since the decrease in error rate and increase in reliability rates tend to level out as the group size increases. For this research a group size of 10 experts was used.

The Delphi technique is initiated by presenting the problem to each member of the group. Each member was asked to provide his comments and opinions on the questionnaire. A cover letter was used to present the problem to the individual group members. When the responses were received, the researcher computed the median and interquartile ranges (i.e., the middle 50 percent of the responses). The information accumulated in the first round then become feedback for the second iteration of questions (3:4-5).

In the second round the respondents were asked to reconsider their responses to the first round and provide additional comments. Members were also requested to critique the answers and comments from other group members. The group members then resubmitted their original comments or revised them (3:5-6). Two iterations were required, for group convergence.

The Delphi technique is not without critics, however. In a 1974 Rand report, Sackman criticized the Delphi technique as being untrustworthy because of its inability to provide verifiable results (25:31-32). He also included in his criticism, the lack of experimental control. Sackman stressed that to produce reliable data, all group members should be subjected to the same environmental factors, and time constraints. However, Sackman could not find "seriously critical literature of any depth" on the Delphi technique (19:73).

The Delphi method is as reliable in predicting group response as is face-to-face discussion, as long as the three characteristics mentioned earlier are maintained and the area of inquiry is difficult to predict. Because the Delphi technique does not conform to experimental tenets, it is not widely accepted. Moreover, poor procedural control can effect the reliability of the research. Experimental methods would be difficult if not impossible to apply to this area of study; therefore, it did not apply.

Survey Development. The Delphi survey used in this research was developed using questions and responses obtained during interviews with logisticians working with space systems and from information gathered during phase one of this research. Items in the survey were aligned to correspond to this study's research questions. The first round Delphi survey is displayed in Appendix C.

Decision Rule. The aim of the Delphi method is to reach consensus on an issue. Several rounds, or iterations, of the survey may be necessary to achieve consensus. However, because of time constraints on this study only two rounds were conducted. For the purposes of this study, consensus was defined as 60 percent agreement. This figure represented a requirement higher than the customary majority rule, yet a reasonable standard. For Likert scale items, 'strongly agree/agree' and 'strongly disagree/disagree' responses were grouped together as a basis for determining consensus. Other survey items were also subjected to the 60 percent consensus rule. A complete listing of first round comments is presented in Appendix D.

<u>Second Round Delphi Survey</u>. Results from the first round were tabulated using a personal computer spreadsheet entitled Quattro. The mean response was computed for each item and examined to determine if 60 percent or greater agreement was met. A consensus ruling was then made for each item. The second round Delphi survey was based on these results. When consensus was reached on a particular item, that item was not repeated. However, consensus item feedback to the Delphi experts showed the percentage who agreed or disagreed with each item. On descriptive items, a response that best fit the mean response was selected and fed back to the participants.

Non-consensus items formed the basis for the second round Delphi survey. The experts were provided with their first round response as well as the mean response of the group. The second round survey is contained in Appendix E.

Individual responses of the group were also included as feedback. Each section of the survey began with responses from the first round that related to that section. Comments relating to specific questions were placed just before the question to help insure the respondents read and considered the responses prior to answering the second round questions. Respondents were also given the opportunity to respond to comments made by other participants. As a result of the synthesizing of responses from round two of the Delphi survey, conclusions were able to be drawn concerning future qualifications and training requirements of space logisticians. Round two comments are contained in Appendix F.

IV. Findings and Analysis

Introduction

This chapter describes the results obtained from the second phase of research. Phase one was the literature review, and is contained in Chapter II. During the second phase of this research, interviews were first conducted with three logisticians working with space systems, to establish a base for a Delphi survey. Once this information was collected a Delphi survey of 10 expert space logisticians was conducted to elicit perceptions on the qualifications and requirements necessary for space logisticians, and to gather opinions whether the Air Force is properly developing its cadre of space logisticians.

Interviews

The purpose of the interviews was to gain a general understanding of space logistics from the point of view of logisticians, working with space systems. This information was then used in conjunction with information gathered in phase one of the research to determine the contents of the Delphi survey.

The interviews consisted of ten questions; four demographic questions to determine qualifications, and six questions relating specifically to space logistics. The interview group consisted of a GS-11 and GS-12 from Sacramento Air Logistics Center, and a Major from the Air Force Systems Command at Wright-Patterson AFB, Ohio. These individuals were selected by HQ/AFLC and HQ/AFSC personnel offices as being knowledgeable in the space logistics arena, but did not meet the criteria as experts.

Interview Results. Those interviewed had an average of two years experience working with space systems, the longest was three years and the shortest was one and one half years. The interview group also had experience in other areas of logistics. Comments received during the interviews are contained in Appendix B along with the interview schedule. Overall results of the last six questions are related below.

Question 5. How does your job fit into the overall picture of space logistics? All of those interviewed worked, at least partially, in the user segment of space logistics. The GS-12 also worked in the control segment. The Major was working on the National Aerospace Plane and saw his work as relating to all four segment.

Question 6. What training did you receive before working with space systems? What do you feel would improve this training? None of those interviewed received training related to space logistics prior to assuming their current duties. The training they did receive, related to their particular speciality, i.e., acquisitions, maintenance, supply etc. The second half of this question is answered in question 7.

Question 7. What additional training, if any, would you add? All of those interviewed felt that short blocks of instruction related to space systems and the space operating environment would be extremely beneficial. Also, short blocks of instructions on logistics concepts and how they relate to space systems. Finally, they felt that system specific courses relating to the system they work with, should be included.

Question 8. What specific qualifications should logisticians possess to work with space systems? There were no additional qualifications mentioned in the interviews that would relate specifically to space systems. A knowledge of computer systems, common sense, and an understanding of LSA and the provisioning process are all common characteristics of logisticians.

Question 9. What other specific skills should logisticians possess to work with space systems? Again, since they all felt that logistics support is the same regardless of the system, there were no skills unique to space systems logistics.

Question 10. What technologies do you feel are driving the space logistics field? In this area there were a number of unique technologies. The concept of on-orbit maintenance of space systems presents, in itself, new ideas for logisticians. But, before on-orbit maintenance and servicing can become a reality, standardization of space systems must take place, as well as strict adherence to ILS. None of these technoiogies actually present anything new to logisticians, rather they are just new challenges to existing logistics practices.

In summary, the lack of structured logistics training for space logisticians presented some difficulty. The requirement to gain the understanding of space systems "on the job" unnecessarily impedes the logistician. Understanding of space systems along with strong computer skills, appeared to be the only unique qualification for space logisticians. Strong computer skills appears to be an Air Force wide requirement, not necessarily unique to space logisticians.

Delphi Survey

The purpose of the Delphi survey was to gain expert opinion in the areas of space logistician development and future Air Force requirements.

The survey consisted of five Likert scale items which questioned the Delphi experts' agreement with statements concerning the qualifications and training of space logisticians, differences between space logistics and logistics in general, and future requirements of space logistics. In addition, the expert was asked to explain each Likert scale response. Twelve open-ended questions were included to obtain information that would help focus problem areas in the development of space logisticians. The Delphi experts were also asked to rate, on a scale of one to five, how they felt the Air force was doing in each segment of space operations against the ten elements of Integrated Logistics Support (ILS). The Delphi experts provided a large number of comments, indicating that they had spent considerable time with the survey. Several respondents included studies they thought would be helpful, and one even included a book he authored relating to the subject. The Delphi experts' comments for the first round are included in Appendix D.

Round One Results. Only six of the ten members of the group responded to the first round survey. Even with a follow up phone call to those members who had not responded, the number could not be increased. Due to time constraints on this study, the first round was cut-off at six responses. A consensus of at least 60 percent of the Delphi experts responding was reached on 3 of the 5 Likert scale survey items and 10 of the 12 open ended questions. Two of the open ended questions asked for information only, and no consensus ruling was made. The consensus rulings were based on the total number of responses to the particular question. Some experts felt they were not qualified to answer particular questions; therefore, their responses are not counted for a consensus ruling. All the round one Likert scale responses are shown in Table 2.

For non-Likert questions, responses were either favorable, unfavorable, or neutral to the questions. A value of two, one, and zero was assigned respectively to these responses. Frequencies were then analyzed to determine if a consensus existed. Responses to the non-Likert questions are arranged by topic in Table 3.

In the final two questions, the experts were given a matrix and asked to rate the four segments of space logistics, against the ten elements of Integrated Logistics Support. The questions were divided so that the experts rated how they felt the Air Force was currently doing and how well they felt the Air Force would be doing by the year 2000. Tables 4 and 5 contain the group average response, the modal response to each item, and the percentage agreeing on ratings. The experts' responses to each of the five topic areas are highlighted below.

Table 2
Likert Responses -- Round One Delphi Survey

Topic		*Ratings 1	2	3	4	5	Mean	Consensus
Space Logistics								
Question 1	**	1	2	0	3	0	2.83	50%
Maintenance and Support								
Question 1		3	1	1	1	0	2.00	66.67% disagree/ strongly disagree
Question 2		0	1	1	3	0	3.40	60% agree
Skills and Qualifications								
Question 1		0	5	1	0	0	2.167	83.33% disagree
Training								
Question 1		0	2	2	2	0	3.00	50%

* Note: 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, and 5=strongly agree

** Note: numbers in the columns indicate the total number of responses received per rating

Space Logistics. The specific response to the Likert scale question concerning space logistics is displayed in Table 2. The experts were split on whether space logistics was different from other areas of logistics. Fifty percent agreed that it was "no different from other areas of logistics," while fifty percent said it was different. Those stating that there was a difference in space logistics cite

Table 3
Non-Likert Responses --Round One Delphi Survey

Topic	*Rating 0	1	2	**Mean
Space Logistics				
Question 2	2	3	1	75% unfavorable
Maintenance and Support				
Question 3	1	5	0	100% unfavorable
Skills and Qualifications				
Question 2	1	4	1	80% unfavorable
Question 3	1	5	0	100% unfavorable
Training				
Question 2	0	2	4	66.67% favorable
Question 3	0	4	2	66.67% unfavorable
Future Requirements				
Question 2	1	4	1	80% unfavorable
Question 3	2	4	0	100% unfavorable
Question 5	0	6	0	100% unfavorable
Question 6	1	2	3	60% favorable

* Note. 0 in the rating indicates no response to the question, 1 indicates a unfavorable response to the question, and a 2 indicates a favorable response.

** Note. The mean score is of those respondents who answered the question. Those who did not respond, related that they were not familiar enough with that particular area to respond.

Table 4. Matrix Responses -- Question 7

ILS Element/Segment	Respondent Ratings					AVG	Mode	% Agree	Rating
Maintenance									
Space	1		4	2	1	2.00	1	0.75	<= Marginal
Launch	2	3	4	4	2	3.00	4,2	0.60	>= Satisfactory
Control	3	3	3	3	3	3.00	3	1.00	Satisfactory
User	3	2	3	2	3	2.60	3	0.60	Satisfactory
Supply Support									
Space	1			2	1	1.33	1	1.00	<= Marginal
Launch	3	3	4	4	2	3.20	3,4	0.80	>= Satisfactory
Control	3	2	3	4	3	3.00	3	0.80	>= Satisfactory
User	3	2	3	2	3	2.60	3	0.60	Satisfactory
Support Equip									
Space	2			2	1	1.67	2	1.00	<= Marginal
Launch	3	3	4	4	2	3.20	3,4	0.80	>= Satisfactory
Control	3	3	3	4	3	3.20	3	1.00	>= Satisfactory
User	3	3	3	2	3	2.80	3	0.80	Satisfactory
*PHS&T									
Space	4	3	4	2	1	2.80	4	0.60	>= Satisfactory
Launch	4	3	3	4	2	3.20	3,4	0.80	>= Satisfactory
Control	3	3	3	4	3	3.20	3	1.00	>= Satisfactory
User	3	3	3	2	3	2.80	3	0.80	Satisfactory
Training									
Space		3	4	2	1	2.50		0.50	
Launch	4	3		4	2	3.25	4	0.75	>= Satisfactory
Control	3	2		4	3	3.00	3	0.75	>= Satisfactory
User	3	2	3	2	2	2.40	2	0.60	Marginal
Technical Data									
Space	4	3	1	2	1	2.20	1	0.60	<= Marginal
Launch	4	1	1	4	2	2.40	1,4	0.60	<= Marginal
Control	3	1	1	4	3	2.40	1,3	0.60	>= Satisfactory
User	3	1	3	2	2	2.20	2,3	0.60	<= Marginal
Computer Support									
Space	5	3	3	2	1	2.80	3	0.60	>= Satisfactory
Launch	4	3	3	4	3	3.40	3	1.00	>= Satisfactory
Control	3	3	3	4	2	3.00	3	0.80	>= Satisfactory
User	3	3	3	2	2	2.60	3	0.60	Satisfactory
Facilities									
Space	5	3	3	2	1	2.80	3	0.60	>= Satisfactory
Launch	5	3	2	4		3.50		0.75	>= Satisfactory
Control	3	3	3	4	3	3.20	3	1.00	>= Satisfactory
User	3	3	3	2	3	2.80	3	0.80	Satisfactory
Manpower & Per									
Space	4	3	3	2	1	2.60	3	0.60	>= Satisfactory
Launch	4	3		4	3	3.50	3,4	1.00	>= Satisfactory
Control	3	3		4	2	3.00	3	0.75	>= Satisfactory
User	3	3	3	2	3	2.80	3	0.80	Satisfactory
Design Interface									
Space	1	2	1	2	1	1.40	1	1.00	<= Marginal
Launch	3	2	1	4	3	2.60	3	0.60	>= Satisfactory
Control	1	2	2	4	2	2.20	2	0.80	<= Marginal
User	3	2	3	2	3	2.60	3	0.60	Satisfactory

Table 5. Matrix Responses -- Question 8

ILS Element/Segment	Respondent Ratings					AVG	Mode	% Agree	Rating
Maintenance									
Space	1	3	4	2	1	2.20	1	0.60	<= Marginal
Launch	3	3	4	4	3	3.40	3	1.00	>= Satisfactory
Control	3	3	3	4	3	3.20	3	1.00	>= Satisfactory
User	3	3	3	2	3	2.80	3	0.80	Satisfactory
Supply Support									
Space	1	3		2	1	1.75	1	0.75	<= Marginal
Launch	3	3	4	4	3	3.40	3	1.00	>= Satisfactory
Control	3	3	3	4	3	3.20	3	1.00	>= Satisfactory
User	3	3	3	2	3	2.80	3	0.80	Satisfactory
Support Equip									
Space	2	3		2	1	2.00	2	0.75	<= Marginal
Launch	3	3	4	4	3	3.40	3	1.00	>= Satisfactory
Control	3	3	3	4	3	3.20	3	1.00	>= Satisfactory
User	3	3	3	2	3	2.80	3	0.80	Satisfactory
*PHS&T									
Space	4	3	4	2	1	2.80	4	0.60	>= Satisfactory
Launch	3	3	3	4	3	3.20	3	1.00	>= Satisfactory
Control	3	3	3	4	3	3.20	3	1.00	>= Satisfactory
User	3	3	3	2	3	2.80	3	0.80	Satisfactory
Training									
Space		3	4	2	1	2.50		0.50	
Launch	3	3		4	3	3.25	3	1.00	>= Satisfactory
Control	3	3		4	3	3.25	3	1.00	>= Satisfactory
User	3	3	3	2	3	2.80	3	0.80	Satisfactory
Technical Data									
Space	4	3	1	2	1	2.20	1	0.60	<= Marginal
Launch	3	3	1	4	3	2.80	3	0.80	>= Satisfactory
Control	3	3	1	4	3	2.80	3	0.80	>= Satisfactory
User	3	3	3	2	3	2.80	3	0.80	Satisfactory
Computer Support									
Space	5	3	3	2	1	2.80	3	0.60	>= Satisfactory
Launch	3	3	3	4	3	3.20	3	1.00	>= Satisfactory
Control	3	3	3	4	3	3.20	3	1.00	>= Satisfactory
User	3	3	3	2	3	2.80	3	0.80	Satisfactory
Facilities									
Space	5	3	3	2	1	2.80	3	0.60	>= Satisfactory
Launch	3	3	2	4	3	3.00	3	0.80	>= Satisfactory
Control	3	3	3	4	3	3.20	3	1.00	>= Satisfactory
User	3	3	3	2	3	2.80	3	0.80	Satisfactory
Manpower & Per									
Space	4	3	3	2	1	2.60	3	0.60	>= Satisfactory
Launch	3	3		4	3	3.25	3	1.00	>= Satisfactory
Control	3	3		4	3	3.25	3	1.00	>= Satisfactory
User	3	3	3	2	3	2.80	3	0.80	Satisfactory
Design Interface									
Space	3	3	1	2	1	2.00	1,3	0.60	<= Marginal
Launch	3	3	1	4	3	2.80	3	0.80	>= Satisfactory
Control	3	3	2	4	3	3.00	3	0.80	>= Satisfactory
User	3	3	3	2	3	2.80	3	0.80	Satisfactory

the environment of space as the primary reason for the difference. The environmental difference is a point of contention by those that believe space logistics is not different. As one respondent stated:

> Logisticians recognize that the basic logistics principles are essentially the same and apply to the air, land, sea, and space. However, the operational environment of space is very difficult. Space logistics concepts must be developed that compensate and adapt to this environment. While the same argument can be made for the differences between air, land, and sea, space presents unique challenges to the logisticians.

Another response simply states, "Logistics provides support, regardless of the environment." Even though the responses to the Likert scale question indicates a split in the opinions of the experts, their written responses indicate that there is agreement. With the exception of one respondent, all of the experts state that the logistics principles are the same, the environment is the only distinguishing factor. The environment can be either political or physical. An example of this response is, ". . . logistics is logistics, it's the politics and language we need to learn." On the side of the physical environment:

> Space logistics differs from other areas because operating environment differs from earthbound by: (1) lack of gravity, (2) thermal, (3) structural, (4) planning constraints, (5) orbital, (and) (6) mechanical considerations. Space logistics requires an in depth understanding of these differences. . ."

The final point in the space logistics topic deals with the military standards used in the ILS process of systems acquisition. The ratings given to the non-Likert scale responses are contained in Table 3. One hundred percent of the experts responding, disagreed with the statement that military standards similar to MIL-STD-1388-1A and MIL-STD-1388-2A should be developed for space systems. The primary reason for their disagreement was that the "current standards are sufficient" and that "tailoring" of these standards to space systems is all that is required. While it is important to develop standardization among space systems, the experts felt that the current standards could adequately produce standardization in space systems if properly applied.

<u>Maintenance and Support</u>. The specific responses to the Likert scale questions concerning Maintenance and Support are displayed in Table 2. Responses to non-Likert scale responses are contained in Table 3. Sixty-seven percent of the experts disagreed with the statement that on-orbit maintenance is too costly to be realistic. They do concede however, that some systems will never be cost effective to maintain. But, servicing rather than discarding a $500 million system is becoming more logical every day. One respondent commented that:

> There is a substantial body of knowledge available that provides conclusive evidence that on-orbit maintenance and servicing is technically feasible and can realize cost savings.

One expert included, with his response, a report that synopsizes studies which have been performed to assess the technical feasibility and cost effectiveness of on-orbit maintenance and servicing. This report is contained in Appendix G.

The Air Force currently launches its space systems through what is called "one contractor processing." However, the Air Force anticipates a large increase in system launches over the next decade that could tax this process. Sixty percent of the experts that responded to this question agreed that the Air Force should try to develop "organic logistics support" for the launch segment. Their reasons for development of the organic support varied from providing, ". . . a more responsive (system) for the war fighting CINCs" to, "self-reliance" following the Challenger disaster. The opponents to organic Air Force support point out the stability contractors provide to system launches. One response states, "The Air Force has historically had difficulty maintaining the talent and experience in its blue suit force to handle the launch segment."

The final point under maintenance and support was to determine how well the Air Force is doing toward "normalizing" space logistics. One-hundred percent of the experts responding, agreed that the Air Force is not doing very well in this area. The primary reasons cited for this lack of adequate response by the Air Force is the Research and Development community, and Air Staff logistics community.

One respondent put it best when he said:

> The R&D community continues to resist any loss of control . . . Before any significant change occurs, a complete change of mentality must take place. The first must take place in the Pentagon and in the DCS/LE community. Space logistics is given lip service with only part time advocacy dependent upon the level of interest by the action officer. Top-down guidance must be developed and promulgated at the Air Staff level before a significant impact can be made to force the space system developers and acquisition agency from the R&D mentality.

Duplication of effort by different agencies is also cited as an example of the lack of normalization.

Skills and Qualifications. Responses to the Likert scale question and the non-Likert questions can be found in Tables 2 and 3 respectively. Eighty-three percent of the experts disagreed to the statement that there are no specific qualifications that space logisticians should possess, outside the realm of other logistics disciplines. Again, the environment was the main factor in their decision. One specific response states:

> Logistics must relate to environment. Aircraft maintenance officers must understand aircraft systems. Space logisticians must understand space systems. Special identifiers may be required similar to C - prefixes for computer systems.

This highlights a point mentioned in another response. A prefix code on AFSCs would help identify space logisticians, and therefore, aid the development of the cadre of space logisticians. One respondent complained:

> . . . our personnel system fails to recognize that we (space logistics) are immature and if space logistics is to "normalize", a knowledge base of individuals must be maintained. Unfortunately, "the system" takes highly qualified individuals making a very positive contribution to normalization of space, and transfers them to other functions for "the greater needs of the Air Force." I believe this is very short sighted.

One respondent put it bluntly and said the qualifications necessary for space logisticians are, "tenacious and ability to get along with obnoxious folks . . . we are the outsiders and still haven't been accepted in concept or existence."

With an expanding role in space, the Air Force will not only need to accept the existence of space logisticians, it will need to insure that an increased number of space logisticians are properly prepared to meet the expanding involvement in space. Eighty percent of the experts that responded, said the Air Force is not taking proper steps to fulfill the expanding need for space logisticians. Again, the Research and Development community, and the Air Staff were cited as major factors for the Air Force failing to fulfill the expanding need. As one respondent stated:

> The Air Force must first recognize that space is no longer a R&D activity . . . At this time the predominant influence remains the R&D community, who essentially decline to recognize that a supporter, other than they themselves, exist.

The steps that the Air Force needs to take to fulfill this need are, at best, ambiguous. One respondent put it bluntly when he said that the Airstaff logistics office needs to better support space.

> First, the Airstaff, AF/LE, must care enough to put strong, vocal individuals in the space log slot (maybe even make it two slots), (and) then support them. AFLC and AFSC must then establish strong organizations with Maj/LtCol level management to force it down into the commands.

Others cite the need for technical courses in space systems as the first step to developing and fulfilling the future requirements for space logisticians. The Ballistic Missile Defense System (BMD) planning is also noted as a point where the Air Force could start developing its cadre of space logisticians. As one respondent who is working on BMD put it, "I . . . don't think logistics is being adequately considered."

One step that could help move the Air Force toward developing a qualified cadre of space logisticians would be to develop a space logistics infrastructure that matches the logistics infrastructure of other major commands. One hundred percent of the experts responding said the Air Force is not doing this. A small step was taken with the organization of Detachment 25, Sacramento ALC, at Peterson AFB, Colorado, called "Pacer Frontier." Pacer Frontiers primary strategy is to centralize, consolidate, and collocate the system management and technical support structure for space and early warning systems with the operational user. But, as one respondent put it, ". . . this is out of step with the rest of the AF." Once again, a respondent blamed the Research and Development community for at least part of the problem.

> The Air Force needs to get the R&D community out of the support business. Also, the satellite support function is treated like a communications function in the operating command. Until it is recognized that space support is not command and control, and should not be subordinated as a communication function, a viable responsive logistics infrastructure will be a long time coming.

Even though all of the respondents felt that the Air Force was not taking proper steps to develop a viable space logistics infrastructure, they did see some positive actions being taken. For instance, "AFLC has designated a lead ALC (Sacramento ALC) for space systems." But, more is needed in terms of identifying and training personnel.

Training. Specific responses to the Likert scale question can be found in Table 2. Ratings given to the non-Likert scale responses can be found in Table 3. Special training will still be required for space logisticians, whether or not space logistics is sufficiently different than other areas of logistics.

The experts could not agree that an overview course, covering such topics as types of systems, orbits, and ground systems/spacecraft interface, was adequate to fill the requirement for space logisticians. The panel was evenly divided between Disagree, Neither agree nor Disagree, and Agree.

Those experts that felt this type of course would be insufficient, again, pointed to the environment of space logistics as the primary reason. Specifically, one respondent said that "hands-on of space operations (was) essential to understand (the) different space environment." Others felt that there should be some type of course that gave space logisticians an "appreciation" of the space environment, but, that an expansion of existing "logistics education" was what was needed, not "new space logistics education."

The experts who agreed with the statement, thought that this type of overview course would be extremely beneficial, as a supplement to "normal" logistic training. By supplementing logistics training with an overview course on space systems, the logistician would have a better "feel" for what was required of the systems he was working with, as well as himself.

Sixty-seven percent of the experts agreed that a Professional Continuing Education (PCE) course on space logistics would be beneficial for the development of logisticians. The strongest response, in favor of a PCE course, said:

> Yes, a two to three week course on the peculiarities of logistics support for space is all that is needed. Any competent logistics specialist would then have sufficient background to provide appropriate support.

The experts also provided specific topics of instruction that should be included in a PCE course. These topics include, the four segments of space operations and their functions, missions, support infrastructure, and maintenance and servicing concepts.

Opinions varied widely on why a PCE course was not necessary. Some felt that simply "tailoring" existing logistics principles to the space environment would be sufficient. Others felt that a PCE course could not provide the depth required to cover the topic. For example, on respondent said, "I think it should be a graduate school area rather than PCE. It is very difficult to maintain the instructor talent in PCE." However this idea of a graduate program for space logistics was not well supported.

Sixty-seven percent of the experts disagreed that a graduate program would be beneficial for space logisticians. The primary reason for the disagreement was in the treatment of space logisticians. For example:

> I do not feel that a separate graduate degree for space logistics is a good idea. Until the concept that logistics for space is different than logistics for everything else has been eliminated, space will continue to have problems.

This sentiment was echoed in other answers as well. One flatly put it, "A loggie is a loggie is a loggie" and did not see the need for specialization to this extent. Most felt that space logistics courses should be included in the current logistics degrees now offered, rather than a separate degree program. Those that thought it was a good idea, saw it as a chance to gain an "in-depth understanding of (the) space operations environment," that might not be gained elsewhere.

Future Requirements. Specific ratings given to the non-Likert scale item pertaining to Future Requirements can be found in Table 3. There were no Likert scale questions in this topic area. Questions one and four in this topic area were for informational purposes only and a consensus ruling on them was not made. Also, questions seven and eight contained the matrix of the four segments of space operations versus the ten elements of ILS. No consensus ruling was made on them as well.

Only three of the experts responded to the first question. However, opinions as to where the Air Force should focus its attention to achieve the best utilization of space assets was extremely varied. One respondent suggested the Air Force focus on the launch segment to achieve better utilization. As he put it, "Launch, Launch, Launch !!! Until the launch segment gets under the control of the pragmatic loggie, we won't (sic) be able to afford the rest of the system." Still another felt that survivability should be the primary concern.

> . . . the vulnerability of space assets is in doubt since we do not have a negation capability. This doubt is demonstrated when other wartime CINCs do not expect to rely on space assets to perform missions in wartime that they routinely perform in peacetime.

Until the "R&D community lets go" and the Air Force changes the "way the mission is going to be accomplished" the problem of negation will remain with us.

Eighty percent of the experts felt that the Air Force was not adequately preparing to meet the challenges of the anticipated increase in operational systems over the next decade. If there was a single point of view mentioned, it would be in personnel. One respondent simply stated that the Air Force was doing "Poorly. Cadre of experts not formed." Another, put it more bluntly, "Badly, (the) Air Staff does not care, AF/LE not manned is Space arena, XO and AQ (have) large contingents. AFSC and AFLC don't care." Steps have been taken; however, to try to meet the future requirements. Several experts cited the establishment of AFLC, Det 25 as the Space Logistics Center. They concede, that even though this is a step "in the right direction . . . there are a lot of variables and a lot of obstacles" that must be overcome if the Air Force is to meet the challenges of the future.

One hundred percent of the experts responding, thought the Air Force was not properly preparing logisticians to meet the future requirements of space. However, most thought that only minor changes were needed to "rectify the situation." Training was cited by nearly all experts as needing the most emphasis. Too improve the situation, one expert stated:

> Educate logisticians about space. Expand logistics curricula to include space. Until a cadre of knowledgeable logisticians is established, modify assignment policies to assure top notch, high caliber individuals are retained in the space logistics business.

Others were not so optimistic about correcting the problem. One expert reiterated his response to the previous question in which he said that the Air Staff and other do not care. However, most felt that training, either in the form of PCE courses or inclusion into a graduate program, would fill the bill of future requirements for space logisticians.

One hundred percent of the experts agreed that the roles of NASA and the DoD were in conflict and not working in the best interest of the United States space program. This conflict is described as an "inherent conflict . . . (and a) bad waste of funds . . . " by one respondent. Others believed that this was changing, but "I would not go so far as to say this is a mutual admiration society. . ." Even though there has been little cross flow in the past, this seems to be changing and joint ventures between NASA and the DoD would be advantageous to both programs, especially in the supportability areas such as maintenance and servicing. Such cooperation could prove extremely beneficial in such areas as the user segment where joint operations could save both manpower and money.

Sixty percent of the experts responding, agreed that the user segment has, at least partially, become separated from the other segments of space operations. They also agree that the user segment should remain separate in order to ensure continued growth. One respondent also added that the control segment is becoming a separate area as well. The separation of the user segment is primarily due to the way in which it is controlled. User segment equipment is treated as communications-electronics equipment, and as such losses some of its identity as space support equipment.

> I doubt this will change any time in the near future; however, the primary weapon system (user) must understand that unilateral changes to a piece of installed equipment cannot be made. The impact on the space segment must be understood. This must be the role of the AFLC space system manager -- system engineering.

In addition, the separate expansion of the user segment will allow for growth that may not occur if the segment is forced to be controlled with the other segments. One respondent put it best when he said, "There is no more need for the user segment to be controlled with the other 3 than for a radio station to control personal radios." However, not all of the experts agreed. Those that did not agree thought the user segment should remain an integral part of the other segments to insure "requirements satisfaction." Without the integration of all four segments the "full extent of the capabilities" may not be reached.

The final two questions asked the expert to rate, on a scale of one to five, how well they thought the Air Force was doing now, in space logistics, and how well the Air Force would be doing by the year 2000. The average group response, the modal response, and the percentage agreeing on one particular rating, can be found in Table 4 and 5 respectively. The ratings of one to five correspond to Unsatisfactory, Marginal, Satisfactory, Excellent, and Outstanding, respectively. For agreement, ratings of 1 and

2, and 3 through 5 were combined. The subtopics below depict each of the ten ILS elements.

Maintenance. The experts felt that maintenance in the space segment was marginal at best, and would not improve much, if any, over the next decade. The decline in percentage, from Table 3 to Table 4, for this segment, was due to a respondent answering question 8, but not question 7. However, there was a noticeable improvement in launch segment maintenance. The response went from sixty percent, that believed that the launch segment was Satisfactory or higher, to one hundred percent that thought it would be Satisfactory or higher.

Only one respondent thought there would be any improvement in maintenance of the control segment, with his rating going from Satisfactory to Excellent. All of the experts agreed that the control segment was at least satisfactory. Sixty percent of those responding agreed that maintenance in the user segment was currently Satisfactory or higher. One respondent felt that there would be some improvement over that next decade, consequently the percentage agreeing rose to eighty percent.

Supply Support. Only three respondents answered question 7, but all three thought that, currently, supply support for the space segment was marginal at best. One additional respondent answered question 8, and thought that over the next decade supply support would be satisfactory. This additional response brought the percentage agreeing down to seventy-five; however, they still agreed that supply support for the space segment would be marginal, at best, by the year 2000. Eighty percent of those responding, thought that supply support for the launch segment was presently satisfactory. The percentage went to one hundred percent over the next decade, with one respondent believing that there would be improvement.

The expert agreed that supply support for the control segment would remain satisfactory over the next decade. However, one respondent thought there would be improvement, thus the percentage agreeing went from eighty percent to one hundred percent. Supply support for the user segment was also thought of as satisfactory through the next decade, with one respondent believing there would be some improvement.

<u>Support Equipment</u>. One hundred percent of the experts that responded feel that support equipment for the space segment is currently, marginal at best. No change is foreseen over the next decade by these experts; however, one additional respondent answered question 8, and he felt that support equipment would by satisfactory by the year 2000. Therefore, the percentage shows a drop from one hundred to seventy-five percent, that feel support equipment for the space segment will be, at best, marginal. In contrast, support equipment for the launch segment is currently viewed as satisfactory or higher by eighty percent of those responding. This figure moved to one hundred percent in

question 8, where one respondent felt that there would be some improvement over the next decade. However, the majority felt that it would only be satisfactory.

Support equipment for the control segment was viewed by one hundred percent of the experts as currently being satisfactory or higher. Eighty percent felt that it was satisfactory, while one felt it was excellent. Over the next decade, no change was seen in this area. User segment support equipment did not show a change over the next decade. Eighty percent of the experts felt that this area would remain satisfactory through the year 2000.

Packaging, Handling, Shipping, and Transportation. Sixty percent of the experts responding felt that Packaging, Handling, Shipping, and Transportation (PHS&T) in the space segment was satisfactory, or higher, and would remain that way through the next decade. None of the experts indicated there would be any improvement in this area. PHS&T for the launch segment was rated currently as satisfactory, or higher, by eighty percent of the respondents. One hundred percent felt that over the, PHS&T for the launch segment would be satisfactory. However, one expert indicated a decline from excellent to satisfactory over next decade. Likewise, one respondent felt that PHS&T in the launch segment would improve from marginal to satisfactory by the year 2000.

One hundred percent of those responding agreed that PHS&T in the control segment was satisfactory, or higher, and would not change over the next decade. Eighty percent of the experts felt that it was satisfactory and would remain that way through the year 2000. PHS&T for the user segment was also viewed as satisfactory but by only eighty percent of those responding. There was no change indicated over the next decade and none of the experts indicated they felt there would be a change.

Training. No agreement was reached on training in the space segment. The experts that responded were split with fifty percent rating current training as satisfactory, or higher, and fifty percent rating training as marginal or unsatisfactory. None of the experts changed their ratings on the second question, indicating they felt that training in the space segment would not improve over the next decade. Training in the launch segment was rated as satisfactory, or higher, by seventy-five percent of those experts responding. One hundred percent rated launch segment training as satisfactory, or higher, by the year 2000. However, one respondent indicated that he felt training would decline from excellent to satisfactory, in the next decade. Also, one respondent indicated that training in the launch segment would improve from marginal to satisfactory by the year 2000.

Current training in the control segment was rated satisfactory, or higher, by seventy-five percent of those responding. By the end of the next decade, one hundred percent of the experts felt that training in the control segment would be satisfactory, or higher. In contrast, sixty percent of those responding felt that training in the user segment was currently marginal. However, eighty percent thought that this would improve to satisfactory by the year 2000.

Technical Data. Technical data in the space segment was viewed as being marginal, at best, by sixty percent of those responding. There was no change indicated over the next decade, with the same sixty percent feeling that technical data would still be marginal, at lower. Launch segment technical data was also viewed as marginal, or worse, by sixty percent of those responding. However, the experts felt that this would improve over the next decade, and eighty percent felt that technical data for the launch segment would improve to satisfactory, or higher, by the year 2000.

Current technical data for the control segment was rated satisfactory, or higher, by sixty percent of those responding. Over the next decade, one respondent felt that this area would improve from unsatisfactory to satisfactory, making it eighty percent of the experts that felt that technical data for the control segment would be satisfactory, or higher, by the year 2000. User segment technical data currently available was rated marginal, or worse, by sixty percent of those responding. However, the experts feel that this area will improve over the next decade, and eighty percent of those responding rated user segment technical data as satisfactory by the year 2000.

Computer Support. All four of the space segments were rated satisfactory, or higher, in the area of computer support. In the space segment, sixty percent of those responding rated current computer support as satisfactory, or higher. There was no change indicated by the year 2000. Computer support of the launch segment was rated satisfactory, or higher, by one hundred percent of those responding. However, one respondent felt that, over the next decade, there would be a decline from excellent to satisfactory in this area.

Current computer support in the control segment was rated satisfactory, or higher, by eighty percent of those that responded. An increased rating by one respondent, brought this percentage up to one hundred for the year 2000. User segment computer support is currently rated satisfactory by sixty percent of those responding. This figure increased to eighty percent, who felt that computer support for the user segment would be satisfactory by the end of the next decade.

Facilities. Space segment facilities were rated as satisfactory, or higher, by sixty percent of the experts responding. The experts did not indicate that there would be any change over the next decade. No ratings changed for the next question. Current facilities for the launch segment were rated satisfactory, or higher, by seventy-five percent of those responding. One of the respondents indicated that this area would decline over the next decade from outstanding to satisfactory. However, one more respondent answered question 8, than question 7, so the percentage agreeing rose to eighty percent.

One hundred percent of the experts rated facilities for the control segment as satisfactory, or higher. There was no change indicated over the next decade, for control segment facilities, by any of the respondents. User segment facilities were rated satisfactory by eighty percent of the respondents, with one, rating them as marginal. None of the experts felt that the facilities would improve by the year 2000, and their ratings did not change.

Manpower and Personnel. Manpower and Personnel for the space segment was rated as satisfactory, or higher, by sixty percent of those responding. One respondent rated this area as marginal, and another rated it as unsatisfactory. None of the respondents felt there would be a change over the next decade with their ratings remaining the same. Launch segment, Manpower and Personnel was rated, current, as satisfactory, or higher, by one hundred percent of those responding. Fifty percent rated this area as satisfactory, and fifty percent rated it as excellent. The experts felt, that by the year 2000, this area would still be satisfactory, or higher; however, seventy-five percent felt that it would only be satisfactory.

Current Manpower and Personnel in the control segment was rated as satisfactory, or higher, be seventy-five percent of those responding. One hundred percent of the experts felt that this area would be satisfactory, or higher, by the end of the next decade. User segment Manpower and Personnel was rated as currently being satisfactory by eighty percent of those responding. One respondent felt that this area was marginal, and would not change over the next decade. However, eighty percent of those responding still felt that user segment Manpower and Personnel would be satisfactory by the year 2000.

Design Interface. Current Design Interface for the space segment was rated as marginal, at best, by one hundred percent of the experts responding. Forty percent of those responding felt that over the next decade this area would improve to satisfactory. However, sixty percent felt that this area would not improve by the year 2000, and rated it as marginal, at best. Launch segment, Design Interface, was rated as satisfactory, or higher, by sixty percent of those responding. One respondent felt this area would improve from marginal to satisfactory over the next decade. Eighty percent of those responding felt that Design Interface for the launch segment would be satisfactory, or higher, by the year 2000.

Current Design Interface, for the control segment, was rated as marginal, at best, be eighty percent of the experts. One expert rated this area as unsatisfactory, but felt it would improve to satisfactory by the end of the next decade. Eighty percent of those responding, rated control segment, Design Interface, as satisfactory, or higher, by the year 2000. User segment, Design Interface, was rated as satisfactory, by sixty percent of those responding. One expert felt that this area would improve from marginal, to satisfactory by the end of the next decade. The percentage, feeling this area would be satisfactory, increased to eighty percent.

Round Two Results. The second round Delphi survey provided feedback of round one results to the experts. Since consensus was reached on all but two questions, only these questions were included in the second round. Also, because of time constraints and the size of the group, the second round was conducted by telephone interviews with the experts. Only five experts participated in the round two survey. One of the original participants had been reassigned to a new station, and had not arrived at the time the second round was conducted.

The Delphi experts' responses to the second round survey are contained in Appendix F. The Delphi experts were given the group average, their first round answer, and a synopsis of responses on both sides of the issue. They were then asked to provide another answer, if they wished, or provide further support for their first response. None of the experts changed their answers from the first round. The non consensus questions were: Topic I, question 1, and Topic IV, question 1. The original answers to these questions may be found in Table 1, with written responses in Appendix D. The round two Delphi survey results are discussed in the following sections.

Space Logistics. Only five of the original six respondents were available for the second round discussion. Sixty percent of those available agreed that space logistics was different, because of the environment, from other logistics areas. However, they did not agree on what form the environment took. Some felt that the physical environment was what made space logistics different from other areas of logistics. One respondent believed that the political environment made space logistics different.

> What I'm saying is the logistics used to accomplish the task is no different. However, the political environment that we have to operate in is so radically different . . .

Even with this statement, he agrees that space logistics is no different, in principle, than other areas of logistics. The political environment may or may not be a legitimate factor for differentiation. Others argue that the environment makes no difference. ". . . a loggie is a loggie, regardless of environment. It is just that the screw driver is exceptionally long for on-orbit maintenance."

Training. No consensus was reached after the second round discussion with the experts. Forty percent of those participating in the second round agreed and forty percent disagreed, that an overview course covering such as the one described, was sufficient training for space logisticians. This training was in addition to "normal" logistics training, and was not intended to be the only training given One respondent repeated that he agreed with the overview course, but felt there needed to be "hands-on" operational training. The idea of "hands-on" operational training was not well received by the others in the group. As one respondent put it:

> I have trouble understanding what they mean by "hand-on" training . . . I don't feel that what he refers to as hands-on training should be required for space logisticians, any more than an aircraft maintenance officer should be required to learn how to fly the aircraft he works on.

Those who disagreed that the overview course was sufficient, argue that an overview course give the logistician a false sense of knowledge.

> I guess I've always been dissatisfied that you can give somebody enough that they understood the problem. I have seen the folks that have come out of the Space Operations course, at Wright-Patt, and I have been very impressed . . . I would think you would need a similar thing for space logistics.

After explaining the way the course is set up for the graduate degree in logistics management at the Air Force Institute of Technology, this respondent thought that a program option in space logistics would be sufficient.

<u>Research</u> <u>Question</u> <u>One</u>:

What skills and qualifications are required of space logisticians? Are they significantly different from other areas of logistics?

Experts responding to the Delphi survey agreed that there were qualifications, outside the realm of other logistic disciplines, that space logisticians should possess.

Even though the experts could not agree on whether or not space logistics was different from other areas of logistics, the environment was the primary difference. The majority of those responding felt that a thorough understanding of this space environment, including on-orbit operations, orbital mechanics, and launch servicing, was essential to the space logistician.

Experience was also selected as a high priority for space logisticians. However, as one respondent stated, "Our personnel system fails to recognize that we are immature . . . ", and moves highly qualified and motivated personnel to other areas, leaving space logistics manned with little experience. One respondent suggested assigning a prefix to current Air Force Specialty Codes (AFSC), so that the personnel system can distinguish space logisticians. Thereby, assisting in maintaining experience in the field. One respondent simply stated that space logisticians should possess these qualification:

> Tenacious and ability to get along with obnoxious folks. It's a new arena - we are the outsiders and still haven't been accepted in concept or existence.

The qualifications mentioned are not significantly different from logistics in general. An understanding of the environment can be transferred just as easily to any other area of logistics. An aircraft maintenance officers must also understand the environment he is required to work in, if he is to properly support the weapon system. And experience, in any career field, is always a positive influence.

Research Question Two:

What are the future requirements for the space logistics field?

Lack of experience in the logistics field will severely hamper the efforts of the Air Force. The role of the Air Force, in space, is projected to increase dramatically over the next decade. If the expansion does occur, the Air Force needs to begin correcting the shortfall now. One respondent suggested that Headquarters USAF/LE increase their manning to better support logistics requirements in space. Also, the Air Force needs to move away from thinking of space systems as Research and Development projects and move toward normalizing a logistics infrastructure to support them.

Normalization has started, to some extent, but much more is needed if space systems are to be properly supported. Air Force Logistics Command has designated a lead ALC for space systems, and Detachment 25, SM-ALC was formed at Peterson AFB, Colorado to provide support for the user and control segments of space operations. However, this is just a start. The Air Force is moving very slowly toward normalization. As one respondent stated:

> The logisticians, and to some extent the operator, support normalization efforts. The R&D community continues to resist any loss of control . . . Before any significant change occurs, a complete change of mentality must take place.

This change of thought must occur from the top down. The Air Staff must give more that "lip service" to space logistics, if normalization, and then support of space is to occur.

Support of on-orbit systems will become a reality in the not to distant future. The experts agreed that on-orbit maintenance and servicing is not just feasible, but economically necessary. Budget crunching is here to stay and the thought of a $500 million system that will simply be discarded if it fails, is no longer a real option, nor is it good business. One of the expert added:

> DoD and NASA studies have demonstrated that while serviceable spacecraft may cost up to 15 percent additional cost, this investment can be recovered in savings from design test, and integration, prior to launch. Serviceable spacecraft is a realistic future goal.

Future requirements for the Air Force logistician, may also include the actual launching of spacecraft. Just as todays logisticians support, and launch aircraft, space logisticians will some day prepare and launch spacecraft. The Delphi experts agreed that the Air Force should acquire an organic logistics support capability for launching systems into orbit. Such activities as routine preflight, postflight maintenance, payload integration, pad maintenance, and launch activities will be included in the space logisticians duties. However, the Air Force may need cooperation from NASA if launch support is to become a reality.

Currently, NASA and the Air Force are not working toward mutual goals. Their respective missions are not conducive to mutual goals and cooperations; however, as one expert states, ". . . there are elements within the respective organizations that are moving together in the spirit of cooperation." This cooperation could prove extremely beneficial to both organizations and to the United States as a whole.

The experts agreed that NASA and DoD roles are not working together toward the best interest of the United States. One expert felt that "DoD and NASA should cooperate and compliment each others mission, supplementing mission unique requirements, capabilities and hardware where necessary." Standardization of system components would greatly assist future support needs for both agencies and make on-orbit repair capabilities more realistic.

The need for such standardization was exemplified by NASAs repair, on-orbit, of the Solar Max and Leasat satellites in 1984. Had these satellites been subjected to standardization requirements, the astronauts would have known exactly what was required before launch. As it worked out, only the sheer ingenuity of NASA and the astronauts, made the repairs possible.

Research Question Three:

Are we adequately preparing people to assume duties in space logistics? What gap exists in developing these individuals? Are we adequately prepared for long-term needs of space logistics?

Overall, the Air Force does a good job preparing people to perform the jobs they are assigned. However, in the area of space logistics, these experts feel that more emphasis needs to be placed on building a cadre of knowledgeable personnel. In order to do this, the Air Force needs to change the way it thinks about space. The thought process needs to move from one of research and development, to that of normalization. Space logistics, although operating in a different and hostile environment, is still logistics and space logisticians need to be educated that way.

According to this research's experts, space logisticians must understand the environment they work in to be fully competent. Training should include, but is not limited to, instruction on the types of systems, orbits, and ground system/spacecraft interface. However, the way this training is conducted is also of importance. The Delphi experts felt that a Professional Continuing Education course covering these topics was "consistent" with other logistics training currently offered. They stressed; however, that this training should be incorporated into existing logistics training and not develop new space logistics education. Also, they did not see training in space logistics improving over the next decade. Therefore, the Air Force must emphasize training for the near term, as well as the long term.

The Air Force has dedicated itself to a future in space; however, over the next decade there will be a substantial increase in operational systems that the Air Force is ill prepared to support. Unless the Air Staff stands behind and supports efforts to normalize space logistics, this effort could "lose momentum." As one expert stated:

> Fielding of the Strategic Defense System (SDS) has the potential for initiating a significant change. The potentially large constellations will force a different approach to space system support . . . If SDS is not fielded, I believe business will continue as usual. There is a complete lack of interest (or maybe I should say total resistance) from the space system designers.

This "lack of interest" needs to be eliminated, if the Air Force is going to successfully support its space requirements for the future.

In order to increase emphasis, the Air Staff needs to completely support space logistics for the Air Force. More emphasis is needed in such areas as training, maintenance techniques, and design interface and standardization.

Summary

This chapter described the results of the second phase of the research process. Interviews were conducted in order to form a framework for a Delphi survey on space logistics requirements of the Air Force. A Delphi survey of 10 space logistics experts was conducted to determine the qualifications of space logisticians and what measures the Air Force should take in developing space logisticians.

The next chapter summarizes to answers to the research objectives and questions. Finally, recommendations for action and future research are presented.

V. Conclusions and Recommendations

The Strategic Defense Initiative (SDI), or Star Wars as the press calls it, raises many questions about the use of space. One of the primary questions for the Air Force, is how to support systems in orbit. The sheer number of systems required for ballistics missile defense is almost unbelievable. Logisticians will be required to support these systems, if SDI is to be even remotely cost effective. But, the Air Force does not have the cadre of space logisticians, qualified, to provide the logistic support necessary.

The purpose of this research was to determine what topics researchers need to focus on in order to begin building the cadre of space logisticians that will be required in the future.

Prior research on development of logisticians, dealt with developing models of senior logisticians, both civilian and military. This research, although concerned with development of logisticians, was not concerned with constructing a model of the typical space logistician. This research effort was concerned primarily with determining what qualifications a space logistician needs, and what measures should be taken to develop these qualifications. Each question is addressed separately on the following pages.

Research Question One

What skills and qualifications are required of space logisticians? Are they significantly different from other areas of logistics?

The opinion of the Delphi experts in this research was that qualification and skills for space logisticians were not significantly different from other areas of logistics. Just as in the prior research on logistician development, experience was the key factor. However, as one expert stated, "Our personnel system fails to recognize that we are immature . . . (and) takes highly qualified individuals . . . and transfers them for the greater needs of the Air Force." Space logisticians must be allowed to grow in experience, if the "greater needs of the Air Force" are to be truly realized.

<u>Research Question Two</u>

What are the future requirements for the space logistics field?

The Air Force must prepare itself to support all segments of space operation, not just the control and user segments. The role of the Air Force in space, is projected to dramatically increase over the next decade. To properly support all segment of space operations, the Air Force must look at developing a support infrastructure similar to other support arenas.

As mentioned earlier, the deployment of SDI will have a dramatics impact of the way space systems are supported If the Air Force is tc be successful in space logistics, it must recognize the requirements for logistics support now, not after systems have been fielded. As with all systems, supportability and maintainability must be programmed in at the design level, not as an after thought.

Programs, such as PACER FRONTIER, need to be nurtured by the Air Force. These types of programs are easy targets for budget cuts and must be protected. As one expert states:

> A space logistics infrastructure will require an investment during a time that resources are in short supply. PACER FRONTIER is an easy target when the operational benefits will not be realized for years to come.

Once a space logistics infrastructure is organized, the Air Force needs to develop its own organic launch segment support. The experts participating in this research felt that in the future, organic, "blue-suit" logistics support for the launch segment would "have the repetitive taskings required to become competent."

The Air Force should develop closer ties with NASA and work toward standardized procedures for common taskings. Currently, each system has to be tailored to fit existing launch vehicles. Standardization would greatly enhance the launch support and minimize costs of placing systems in orbit.

Finally, the experts agreed that the four segments of space operations should not be controlled as one unit. The four segments, in particular the user and control segments, must be allowed to grow on their own. One expert stated that, "There is no more need for the user segment to be controlled with the other 3 than . . . a radio station to control personal radios" However, the Air Force must ensure that the space mission of any equipment be considered before changes to that equipment are made.

Research Question Three

Are we adequately preparing people to assume duties in space logistics? What gap exists in developing these individuals? Are we adequately prepared for long-term needs of space logistics?

The Air Force is not adequately preparing people for space logistics. Logistics training in space logistics is desperately needed. Overview courses on specific topics of space operations will go a long way toward educating people in the differences of space logistics. A PCE course needs to be established that gives logisticians a feel for the environment of logistics in space, as well as specifics on system requirements. Although the experts disagreed that a graduate degree in space logistics was required, they felt space logistics courses should be included as part of the core curriculum of current logistics degrees.

Since experience is the best teacher, the Air Force needs to allow the space logistician to mature. By doing so, the Air Force can build a cadre of knowledgeable space logisticians that will be able to c[illegible] the gap of supportability for space systems.

In order for the Air Force to prepare for the long-term needs of space logistics, a new thought process must develop.

Starting from the Air Staff level, space logistics must be recognized as a necessity, not just as a spin off of Research and Development.

Recommendations

In an attempt to answer the research questions, additional questions were raised by this research. Recommendations for future research in the area of space logistics and space logistician development are suggested.

1. Since this research did not attempt to "model" the space logistician, additional research using the AFIT Models as a base, may produce a guide for space logistician career development. This model may not be significantly different than those already developed; however, as space logistics grows, formal career guidance will be necessary.

2. Further research should also be conducted to determine, to what extent, NASA and DoD should cooperate. Specifically, should these agencies roles be more closely interrelated to develop a more enhanced space program.

3. In order for the Air Force to build a cadre of space logisticians, experienced, highly motivated, and highly qualified people need to be maintained in the space logistics arena. Further research should focus on determining what measures the Air Force should take to keep experienced personnel in space logistics.

4. The acquisition process for space systems does not follow the same path as the acquisition process for other major systems. Further research is needed to clarify the

acquisition process and bring it more in line with other acquisition processes. This includes the standardization of components, and reliability and maintainability issues.

5. With the projected increase in Air Force launches over the next decade the Air Force has a perfect opportunity to become self sufficient in space logistics. Further research is needed to determine the feasibility of the Air Force developing organic logistics support of the launch segment of space logistics.

6. Before the Air Force can begin to build a cadre a space logisticians, we must first move toward normalizing the existing space logistics infrastructure. Follow-on research is needed to determine specific steps the Air Force should take to normalize space logistics.

7. In order to develop a qualified cadre of space logisticians the Air Force needs to implement a quality training training program. Further research is needed to refine, to the specifics, the type of instruction needed and course curriculum.

8. This study was only exploratory in nature, and the results should not be generalized outside the context of this study. The experts who participated in this study perceive a lack of concern for space logistics throughout the Air Force. Further research should extensively survey personnel involved in space logistics to determine if this and other apparent trends are in fact as they appear in this study.

9. If standardization of space systems is to become a reality, the standardization process must begin early in the acquisition process. MIL STD 1388-1A and MIL STD 1388-2A are used together for the purpose of ensuring ILS elements are a part of the design. Currently, these standards are not properly configured for space systems acquisition. Further research should focus on determining what factors need to be included in the military standards to better support space systems acquisition.

10. Recommendation of studies, such as the "Commercial Practices Studies" have not been fully complied with by Air Force Space Command. Further research should be conducted to determine what recommendations have been complied with, how well these recommendations are working, and why some recommendations were not complied with. Other studies should be researched and included as well.

Appendix A: Glossary of Key Terms

Control Segment: The control segment is the ground based link to the satellite that controls its movement and receives information about the satellites position. The three main functions of the control segment are telemetry, tracking and communications.

Integrated Logistics Support: A disciplined, unified and iterative approach to the management and technical activities necessary: (1) integrate support considerations into system and equipment design, (2) develop support requirements that are related consistently to readiness objectives, to design, and to each other, (3) acquire the required support, and (4) provide the support during the operational phase at minimum cost.

Launch Segment: The launch segment inserts spacecraft into orbit or elsewhere in the space medium and should include getting the satellite to the launch pad and the process required to land and turnaround a reusable transportation vehicle.

Logistics Support Analysis: The selective application of scientific and engineering efforts undertaken during the acquisition process, as part of the system engineering and design process, to assist in complying with supportability and other ILS objectives.

Military Logistics: A fully integrated system of processes which must be used to support the military operations of an organization, including combat. Although recent logistics doctrine changes this includes all areas which support combat, this survey is directed toward space logistics, if there is such a thing.

Space Logistics: Because of the uniqueness of space operations, the definition of military logistics must be applied across the four segments of space operations. Space logistics must be a fully integrated system of processes which must be used to support space operations in the launch segment, the space segment, the control segment, and the user segment.

Space Segment: The space segment includes on-orbit operations and servicing of the spacecraft or satellite.

User Segment: The user segment operationally interacts with the space segment to give utility to operations. The logistics of the user segment is primarily the number and information requirements of the user and the standardization of software and hardware to minimize maintenance problems.

Appendix B: Interview Schedule and Responses

1. What is your current rank/grade?

2. What command are you assigned to?

3. How long have you worked in your present job?
With space systems?

4. What other areas of logistics (if any) have you worked in?

5. Space logistics is divided into four segments (launch, space, control, user). How does your job fit into the overall picture of space logistics?

GS-12: "I think of space logistics as having 3 segments, the satellite, the C3 segment, and the user segment. My responsibility was for system management of the C3 segment and user segment for systems which were past IOC. This included item management, supply support, configuration management, as well as acquisition support of systems still in development."

GS-11: "I work with the ground, or user segment, but the users in AFSPACECOM are also responsible for command and control of the spacecraft. We in AFLC manage the equipment used directly and for command and control. We, after PMRT, jointly with Systems Command are responsible for insuring the spacecraftto ground interface still works as ground equipment is modified and spacecraft are replaced with later models. So, primarily user, but all segments to some extent."

Major: "I would have a hard time catagorizing it into one of those (segments) to tell you the truth."

6. What training did you receive before working with space systems?

GS-12: "None."
Interviewer: "You received no space related logistics training?"
GS-12: "That's correct."

GS-11: "I had plenty of training in supply and maintenance that directly related to those two disciplines. After transferring to Materials Management my training was limitedd to generic AF maintenance policies, equipment techniques, and specific management systems. The training I received was good and I have no complaints."
Interviewer: "But, you received no space related logistics training?"
GS-11: "Not specifically space logistics training, what I learned specifically about space systems was picked up on the job."

Major: "None."
Interviewer: "So it was just general logistics training?"
Major: "Correct."

7. What additional training, if any, would you add?

GS-12: "Short blocks of courses on space systems: types of satellites; launch requirements; what the components are and how they interrelate; and logistics concepts, feasibility for on-board maintenance, advantages and disadvantages of three levels of maintenance, R&M issues as they apply to space systems. Also, some training on how to support commercial, off-the-shelf equipment which seem to abound in the ground segment. Is full development data available and is procuring it cost effective."

GS-11: "I do believe that a requirement exists for an overview course on space systems to include types of systems or spacecraft, types of orbits, and ground system/spacecraft interface types. In addition, logisticians should take system specific courses to understand the system they are assigned to. How technical the logisticians job is should determine the technical level of the course attended. I know that ATC buys courses for each system and I believe we should take advantage of some of them."

Major: "I think it would be a damn good idea if they (the Air Force) would develop a separate program to train space systems logistics, and separate it from general logistics training. A general orientation into space systems and what is involved in the infrastructure of space systems is."

8. What specific qualifications should logisticians possess to work in space systems? If none, why not?

GS-12: "Common sense, the ability to translate principles and concepts which were developed for aircraft to the space arena where you are now dealing with onesies and twosies.

And, from the AFLC side, a logistician should get smart on LSA and provisioning processes because 90 percent of the real problems seem to relate to late delivery of spares."

GS-11: "My first inclination is to mention at least a limited knowledge of computer systems; the user segment is typically made up of a bunch of powerful computers and not much else. On second thought however, I believe that aircraft, missiles, and even munitions are becoming dominated by computers. So, coming in, a logistician for space need be no different than one for other disciplines."

Major: "Well, first of all a general overview course like I mentioned before. I would say in engineering, some type of engineering background, but I guess thats true of all logisticians really. Thats about all I can think of."

9. What other specific skills should logisticians possess to work with space systems? If none, why not?

GS-12: "I can't think of any skill per se. It is more an ability to process a wide variety of data from a multitude of sources and synthesize this into a logistics support concept."

GS-11: "Again, there isn't anything all that unique about space systems to require specific skills not found elsewhere. For years space systems have been considered some how different and were managed outside the standard Air Force system. Fortunately, the Air Force is getting away from this wasteful practice beginning with the Defense Meteorological Satellite Program."

Major: "I can't think of any, off hand."

10. What technologies do you feel are driving the space logistics field?

GS-12: "Computer technology including fiberoptics. Also, the availability of chips from off-shore sources for which we do not have a second source will continue to be a problem if the defense industrial base continues to erode. Vulnerability requirements will change in response to development of Star Wars capability."

GS-11: "A big problem still in Air Force space systems is launch vehicles. They are expensive or unreliable. Civilian computer advances are a major factor because space systems are largely made up of commercial off-the-shelf computers. Looking to the future, we are seeking methods of maintaining spacecraft instead just replacing them. Even spacecraft will someday PMRT to AFLC. Another push is toward more, smaller, cheaper satellites, instead of a few, large, expensive, and therefore, vulnerable ones. Clearly further miniaturizationof electronic components is the key."

Major: "Oh boy! The big technology I see coming forward on this program is in materials. We have not even developed yet the material we are going to use on this vehicle (National Aerospace Plane). But just looking at some of the exotic materials and composites that are being studied, I think it's going to be a real big driver in inspection requirements and maintenance requirements. We need to drive out heavy maintenance requirements like in the space shuttle. We need something that is robust. Another thing we are looking at on this vehicle is hydrogen. Some large cryogenic uses, especially if we build follow on vehicles to the X-30, that use hydrogen and are going to be flown on a regular basis we are talking some fairly large cryogenic uses. On this particular vehicle we are talking about using slush hydrogen that will require very special logistics support because of the temperature requirements to maintain it in a slush form."

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY
WRIGHT-PATTERSON AIR FORCE BASE OH 45433-6583

Appendix C: Round One Delphi Survey

Colonel George J. Sawaya
SM-ALC/MMB
McClellon AFB, Ca 95652-5609

Dear Col Sawaya:

Thank you for agreeing to participate in this AFIT Delphi survey. The purpose of this research is to determine the qualifications and requirements of space logisticians. You were selected to participate in this important research because your experience and insight qualify you as a space logistics "expert". Your opinions and comments will be combined with those of other "experts" to determine what the qualifications and requirements of the Air Force space logistician are.

The attached Delphi survey solicits your personal opinions in a number of areas. To assist in this research, please complete the survey and return it in the enclosed envelope within 7 days. As soon as all the responses are compiled, a second Delphi survey will be mailed to you.

You comments, suggestions, and ideas regarding this research are welcome and encouraged. All responses will be treated as confidential and anonymity will be maintained. If you have any questions about this survey please call me collect at (513) 252-2564, or Autovon 785-6569. Thank you for making time to share your expertise.

STEWART G. CARR, Capt, USAF
Air Force Institute of Technology
School of Systems and Logistics

2 Atch
1. Delphi Survey
2. Return Envelope

Round One Delphi Survey

1. Survey Objective:

a. To obtain expert opinion to determine if there is a significant difference between space logisticians and logisticians in general, and what the qualifications of space logisticians should be.

b. To determine what steps, if any, the Air Force could take to develop space logisticians.

2. Definitions

a. Military Logistics: A fully integrated system of processes which must be used to support the military operations of an organization, including combat. Although recent logistics doctrine changes this includes all areas which support combat, this survey is directed toward space logistics, if there is such a thing.

b. Space Logistics: Because of the uniqueness of space operations, the definition of military logistics must be applied across the four segments of space operations. Space logistics must be a fully integrated system of processes which must be used to support space operations in the launch segment, the space segment, the control segment, and the user segment.

c. Launch Segment: The launch segment inserts spacecraft into orbit or elsewhere in the space medium and should include getting the satellite to the launch pad and the process required to land and turnaround a reusable transportation vehicle.

d. Space Segment: The space segment includes on-orbit operations and servicing of the spacecraft or satellite.

e. Control Segment: The control segment is the ground based link to the satellite that controls its movement and receives information about the satellites position. The three main functions of the control segment are telemetry, tracking and communications.

f. User Segment: The user segment operationally interacts with the space segment to give utility to operations. The logistics of the user segment is primarily the number and information requirements of the user and the standardization of software and hardware to minimize maintenance problems.

3. General Comments:

a. The subject areas covered in this questionnaire are not meant to be complete or exhaustive. Instead, the coverage is designed to stimulate your thinking.

b. Your participation and honest opinions are key to the success of this research project. There are no right or wrong answers. Therefore, all your ideas and brainstorming comments should be included. In the second round of questioning, these ideas may spark additional comments from participants.

c. At least two rounds of questioning will be needed to arrive at a group consensus. Each round should not take more than one hour of your time. After the first round, all responses will be compiled and given back to you at the start of the second round. You will be provided an executive summary of this research after it is completed.

d. Many of the questions call for an answer along a scale. Others ask only for your personal comments.

e. The number in the upper right-hand corner of the questionnaire is for survey control purposes only. Please be assured that complete anonymity will be enforced.

4. Specific Instructions:

a. When a question calls for an answer along a scale, please circle the number which most accurately reflects your judgment on that question or statement.

b. Please write the rationale for your answers, especially for those areas where you feel strongly. Add any illustrations, examples, or experiences you have had that will help the other participants understand your response. Feel free to continue your comments on the back of the survey sheets. Please number your comments so they correspond to the question you are answering.

c. Any ideas or recommendations you have for improving space logistician development should also be included with your responses. Your ideas will be shared with others who care about space logistics and space logistician development.

d. The last page of this survey is for additional comments you feel are pertinent to this study.

THANK YOU FOR PARTICIPATING IN THIS SURVEY.

TOPIC I: SPACE LOGISTICS

1a. Interviews conducted for this research, indicate that space logistics is no different than any other area of logistics. Would you: (Please Circle your response)

1	2	3	4	5
strongly disagree	disagree	neither agree nor disagree	agree	strongly agree

1b. Why do you feel that space logistics is different/not different from other areas of logistics?

TOPIC I: SPACE LOGISTICS (continued)

2. Do you feel the current Military Standards are sufficient for space systems or should Military Standards similar to MIL STD 1388-1A and 1388-2A be developed specifically for space systems? Why or why not?

TOPIC II: MAINTENANCE AND SUPPORT

1a. Circle your response to the following statement:

Maintenance of on-orbit systems is too costly to be realistic. The Air Force should continue to focus on systems that are extremely reliable and forget about repairing systems already on orbit:

1	2	3	4	5
strongly disagree	disagree	neither agree nor disagree	agree	strongly agree

1b. Justify your response to the above statement.

TOPIC II: MAINTENANCE AND SUPPORT (continued)

2a. The "one contractor processing" concept for system launches is not in the best interest of the Air Force. The Air Force should have its own organic logistics support for the launch segment. (e.g., routine preflight, postflight maintenance; payload integration; pad maintenance; and launch activities) Would you: (Please circle your response)

1	2	3	4	5
strongly disagree	disagree	neither agree nor disagree	agree	strongly agree

2b. Why do you feel the Air Force should/should not have its own organic logistics support for systems launches?

----

3. In your opinion, how well is the Air Force doing toward "normalizing" space logistics?

TOPIC III: SKILLS AND QUALIFICATIONS

1a. Interviews conducted for this research, indicate that there are no specific qualifications that space logisticians should possess outside the realm of other logistic disciplines. Would you: (Please circle your response)

1	2	3	4	5
strongly disagree	disagree	neither agree nor disagree	agree	strongly agree

1b. What specific qualification, if any, do you feel space logisticians should possess to work with space systems? If none, why not?

TOPIC III: SKILLS AND QUALIFICATIONS (continued)

2. If the Air Force role in space expands as projected over the next decade, there will be a dramatic increase in the number of logisticians needed to adequately fill requirements. In your opinion, is the Air Force taking proper steps to fill this need? What steps, if any, should the Air Force take to meet this requirement?

----

3. Have steps been taken to organize the Air Force space logistics infrastructure to match that of the MAJCOMs? What steps, if any have been taken? If none, what steps should be taken?

TOPIC IV: TRAINING

1a. Logisticians interviewed for this research indicate that any training they received for space logistics was primarily in the form of On the Job Training. However, they also indicated that they would like to have, at least, an overview course in space logistics. The following statement comes from one of the interviews, but was supported by others. Circle your response to the statement.

"Training for space logisticians should consist primarily of an overview course on space systems that includes the types of systems, orbits, and ground system/spacecraft interface."

1	2	3	4	5
strongly disagree	disagree	neither agree nor disagree	agree	strongly agree

1b. Why do you feel this type of training would be sufficient/insufficient for space logisticians? What disciplines or areas of expertise do you feel should be provided to space logisticians?

TOPIC IV: TRAINING (continued)

2. Currently, Professional Continuing Education (PCE) courses provide additional training for logisticians in a variety of specialties. These courses are provided by the Air Force Institute of Technology and are two to three weeks in length. Should a PCE course be established specifically for space logisticians? Why, or why not? If so, what specific topic(s) should be included?

3. Currently, the Air Force Institute of Technology offers a graduate degree in Space Operations. Do you feel that a graduate degree, focusing on Space Logistics, would be beneficial to logisticians working with space systems? Why or why not? Should the Air Force Institute of Technology begin such a program?

TOPIC [illegible]: FUTURE REQUIREMENTS

1. The current position of the Air Force, in relation to space missions, can be compared with trying to find a mission for the airplane, when it first appeared. Where do you feel the Air Force should focus its attention to achieve the best utilization of space assets? What new technologies are emerging in the space logistics field?

2. With the anticipated increase in operational systems over the next decade, how well is the Air Force prepared to meet the logistics challenges?

TOPIC 5: FUTURE REQUIREMENTS (continued)

3. Do you feel that the Air Force is adequately preparing space logisticians to meet the challenges of these new technologies? Why, or why not?

4. What do you feel the Air Force needs to do, if anything, to better prepare space logisticians to meet future challenges?

TOPIC V: FUTURE REQUIREMENTS (continued)

5. How well are the individual roles of NASA and the DoD defined? Do these roles work in harmony or are the two in conflict as far as the best interest of the United States is concerned?

----

6. With the anticipation of continued integration of user equipment in strategic aircraft, and multiservice and special government agency role expansion, do you feel that the user segment, of space operations has become separated from the other three segments? Do you feel that it should or should not be separate from the other segments? Why/Why not?

TOPIC V: FUTURE REQUIREMENTS (continued)

7. Using the elements of Integrated Logistics Support, and the four segments of space logistics, rate how you feel the Air Force is <u>currently</u> doing in space logistics.

1=UNSATISFACTORY 2=MARGINAL 3=SATISFACTORY
4=EXCELLENT 5=OUTSTANDING

	Space	Launch	Control	User
Maintenance				
Supply Support				
Support Equipment				
*PHS&T				
Training				
Technical Data				
Computer Support				
Facilities				
Manpower & Personnel				
Design Interface				

* Packaging, Handling, Shipping, and Transportation

8. Now, rate how you feel the Air Force will realistically be doing by the year 2000.

1=UNSATISFACTORY 2=MARGINAL 3=SATISFACTORY
4=EXCELLENT 5=OUTSTANDING

	Space	Launch	Control	User
Maintenance				
Supply Support				
Support Equipment				
*PHS&T				
Training				
Technical Data				
Computer Support				
Facilities				
Manpower & Personnel				
Design Interface				

* Packaging, Handling, Shipping, and Transportation

ADDITIONAL COMMENTS

Appendix D: First Round Responses

TOPIC I: Space Logistics

General Comments Question 1:

Respondent 001:
"It is different because we have not been involved with this arena. Hence, we as loggies don't understand the subtleties of the culture - logistics is logistics, it's the politics and language we need to learn. The basic logistics is unchanged."

Respondent 002:
"Some processes such as contracting and provisioning must proceed at an accelerated pace, but the basic logistic requirements are the same."

Respondent 003:
"Currently space logistics is considered to be different by the development and acquisition community. This mentality probably evolved because for many years the developer, acquisitions agency, operator, and supporter of space systems was one and the same--the research and development community. As space system control moves out of the R & D environment and is assimilated into the operations community, a more traditional approach to logistics is evolving. While this evolution has been slow it continues but with strong reluctance from the R & D community. Logisticians recognize that the basic logistics principles are essentially the same and apply the air, land, sea, and space. However, the operational environment of space is very difficult. Space logistics concepts must be developed that compensate and adapt to this environment. While the same argument can be made for the differences between air, land, and sea, space presents unique challenges to the logisticians."

Respondent 006:
"Space logistics differs from other areas because operating environment differs from earthbound by (1) lack of gravity, (2) thermal, (3) structural, (4) planning constraints, and (5) orbital, (6) mechanical considerations. Space logistics requires an in depth understanding of these differences, will preclude wrong assumptions about operations and performance of equipment on-orbit."

Respondent 008:
"Logistics provides support, regardless of the environment."

Respondent 009:
"Only the logistics for the space segment is different. What makes the space segment different is that the environment is difficult to access. This means from the combat operations standpoint, the space power that has the best logistics

capability has the upperhand. There is a definite parallel between this issue and British sea power between 1700 - 1900. I suggest you refer to the last two chapters of my book."

General Comments Question 2:

Respondent 001:
"Current standards are sufficient. While I believe space logistics is different, I also believe it is the same at the basic logistics element and using common tailoring techniques will allow one to use most of the existing specs and STDs very effectively."

Respondent 002:
"NO. I am strongly opposed to the development of separate standards for space when small modifications of existing standards is sufficient in most cases."

Respondent 003:
"Military standards need to be established for standardization and commonality among space systems. I am talking about standards for design interfaces such as refueling and electrical connectors. New standards are not required for those standards such as the two you cite, MIL STD 1388-1A and 2A. These standards and all acquisition related standards should be tailored for the specific application."

Respondent 006:
"It is important to develop interface standards between DoD and NASA for on-orbit servicing. Such standards should include orbital replacement unit interfaces between ORU and spacecraft bus, refueling connectors, data and communication protocols and interfaces between operational tools and robotic manipulators."

Respondent 008:
"Don't know."

Respondent 009:
"Not familiar enough with the standards to comment."

TOPIC II: Maintenance and Support

General Comments Question 1:

Respondent 001:
". . . This area is totally misunderstood and is a vital part of the space mystique. Many spacecraft will never be economical to maintain but with fundamental changes in the thought process tremendous savings can be had - as well as increased reliability and readiness."

Respondent 002:
"On-orbit repair that extends the useful life of a $500M+ system is becoming to be a more logical approach every day. Orbiting robotic spares platforms could repair and restore satellite quicker than a new launch would and could reduce the number of launch ready spares required."

Respondent 003:
"As stated, your statement is correct. It would be unrealistic to pursue repairing existing systems on-orbit that have not been designed for on-orbit repair. Future space systems must be designed for on-orbit maintenance. There is a substantial body of knowledge available that provides conclusive evidence that on-orbit maintenance and servicing is technically feasible and can realize cost savings. Attached is a report prepared for USSPACECOM/J4-J6L by SSD/ALI (see Appendix G) that synopsizes studies which have been performed to assess the technical feasibility and cost effectiveness of on-orbit maintenance and servicing."

Respondent 006:
"Parametric analysis can determine, for a given program, whether or not this statement is true. Many factors such as transportation cost, fuel budget and cost, service cost, . . (unreadable words) are all factors in cost equations. DoD and NASA studies have demonstrated that while a serviceable spacecraft may cost up to 15 percent additional cost, this investment can be recovered in savings from design test, and integration above, prior to launch. Serviceable spacecraft is a realistic future goal."

Respondent 008:
"Cost needs to include all costs including risk of failure."

Respondent 009:
"The cost effectiveness of on orbit repair is a function of the orbit. Would refer you to many studies done in the 1970's on the space tug for some insight."

General Comments Question 2:

Respondent 001:
"The AF launched the predecessors (sic) of every expendable out there. Once again a thought process change is required."

Respondent 002:
"With the advent of the ALS and the requirement of 10-20 launches per year, organic support will have the repetitive taskings required to become competent."

Respondent 003:
"The current launch infrastructure should continue to be supported as is. It would be too costly and technologically too difficult to establish an organic capability--assuming you mean a blue-suit capability when you say organic. Future launch systems must be designed to be more responsive to the war fighting CINC. Rapid turn-around of launch facilities with reduced launch vehicle processing and integration times must be a design standard. The one-to-one match of launch vehicle to space vehicle must be eliminated. The launch vehicles must be designed to accept any and all payloads thus the requirements for a standardized payload interface design standard. This does not necessarily mean a blue-suit organic capability. It does mean buying the necessary data and support equipment to put launch in a competitive posture and if possible evolve into a blue-suit capability. It does mean assuring that the launch infrastructure can meet was time tasking requirements."

Respondent 006:
"Unable to respond, don't know the Air Force system."

Respondent 008:
"Self-reliance - i.e., need to develop Air Force capability in aftermath of Challenger accident."

Respondent 009:
"The Air Force has historically had difficulty maintaining the talent and experience in its blue suit force to handle the launch segment."

General Comments Question 3:

Respondent 001:
"AFLC is doing fair but not addressing anything but control and user segment. AFSPACE DIV has no concept of what support is for launch and on-orbit segment. Space Command is starting to understand Ops (sic) control of launch segment and has not."

Respondent 002:
"As long as programs are allowed to continue to claim that they are 'unique' and therefore should not conform, the AF will never be successful. The duplication of effort by SIO and those required of an SPM is an example of the current lack of normalization."

Respondent 003:
"The Air Force is moving, but moving very slowly. The logisticians and to some extent the operator support normalization efforts. The R & D community continues to resist any loss of control over space systems--be that operational or support. Before any significant change occurs, a complete change of mentality must take place. The first must take place in the Pentagon and in the DCS/LE community. Space logistics is given lip service with only part time advocacy dependent upon the level of interest by the action officer. Top-down guidance and policy must be developed and promulgated at the Air Staff level before a significant impact can be made to force the space system developers and acquisition agency from an R & D mentality. Certain design constraints that consider supportability must be imposed on the developers and acquisition agency similar to that imposed on aircraft developers."

Respondent 006:
"Unable to respond, don't know the Air Force system."

Respondent 008:
"Significant lag considering how long we have been in space."

Respondent 009:
"Think the issue is in doubt. Refer to General Piotrowski's command briefing to view the large doctrinal split between USSPACECOM and AFSC on this issue. The general wants to go to the Soviet model (rapid launch capability, less capable satellites, etc.) rather than the current AFSC approach."

TOPIC III: Skills and Qualifications

General Comments Question 1:

Respondent 001:
"Tenacious and ability to get along with obnoxious folks. Its a new arena - we are the outsiders and still haven't been accepted in concept or existence."

Respondent 002:
"As with any logistician, field experience is the best teacher."

Respondent 003:
"If you look at the space environment in its totality, there will be most certainly special qualifications required. As there are specialists in aircraft maintenance there will be specialists in on-orbit maintenance and servicing. If however, you are talking as generality, no special qualification should be required. Space education is required, not new logistics education. I will admit that at this time our cadre of knowledgeable space logisticians is very fragile. Our personnel system fails to recognize that we are immature and if space logistics is to 'normalize', a knowledge base of individuals must be maintained. Unfortunately, 'the system' takes highly qualified individuals making a very positive contribution to normalization of space and transfers them to other functions for 'the greater needs of the Air Force.' I believe this is very short sighted."

Respondent 006:
"Understanding of on-orbit operating environment, orbital mechanics, space operations planning templates, launch service and their constraints."

Respondent 008:
"Logistics must relate to environment. Aircraft maintenance officers must understand aircraft systems. Space logisticians must understand space systems. Special identifiers may be required (similar to C - prefix for computer systems)."

Respondent 009:
"For space logistics, the logistician must understand the environment."

General Comments Question 2:

Respondent 001:
"No. First, the airstaff AF/LE must care enough to put strong, vocal individuals in the space log slot (maybe even make it two slots) then support them. AFLC and AFSC must then establish strong organizations with Maj/Lt Col level mgt (sic) to force it down into the commands."

Respondent 002:
"The current emphasis of identifying the need for space experience in the MAJCOMs has been a significant step for the AF. This type of effort emphasizes the fact that many of the 'unique' space requirements are actually quite common."

Respondent 003:
"NO. The Air Force must first recognize that space is no longer an R & D activity. It must establish the respective roles of the developer-acquisition agency, the operator, and the supporter. It must then develop appropriate policies to implement the appropriate roles. At this time the predominant influence remains the R & D community, who essentially decline to recognize that a supporter other than they themselves exist."

Respondent 006:
"Unable to respond, don't understand Air Force activities."

Respondent 008:
"If Air Force is taking steps, they are not readily apparent. Technical courses in space systems are needed."

Respondent 009:
"Think the major impact will be the deployment of a BMD system in space. I am involved in BMD planning and don't think logistics is being adequately considered."

General Comments Question 3.

Respondent 001:
"Slight. DET 25, SM-ALC is a first step - - - but it is out of step with the rest of the AF."

Respondent 002:
"The biggest mistake that Space Command has made was combining the KR and LG into an LK organization. The structure makes even the most simple operations difficult i.e. having maintenance of hardware under one asst DCS, supply under another asst DCS and software under a totally separate unit."

Respondent 003:
"Do not know what you mean by this question. Supposedly, AFSC is performing its traditional role of developer-acquisition agency. AFSPACECOM is the operator, and AFLC is the supporter. From a logistics perspective this has been accomplished to some extent. Most ground segments are supposed to plan for PMRT. The same does not apply to the space segment. While AFSPACECOM 'flies' the satellite and performs the 'organizational' maintenance function of health and welfare, anomaly resolution is generally relegated to a R & D function. AFLC has no capability--and I do not see any developing through the mid-term -- to perform its traditional system engineering function for the satellite. This function remains with the R & D community. The Air Force needs to get the R & D community out of the support business. Also, the satellite support function is treated like a communication - ADP function in the operating command. Until it is recognized that space support is not command and control and should not be subordinated as a communication-ADP function, a viable responsive logistics infrastructure will be a long time coming."

Respondent 006:
"Unable to respond."

Respondent 008:
"Somewhat. AFLC has designated a lead ALC for space systems. More in terms of identifying and training personnel is needed."

Respondent 009:
"See above." (Think the major impact will be the deployment of a BMD system in space. I am involved in BMD planning and don't think logistics is being adequately considered.)

TOPIC IV: Training

General Comments Question 1:

Respondent 001:
"Since space is still 'different' from what most loggies are raised with, a basic primer course such as the Space and Missile orientation course at VAFB or the SSD orientation course is extremely valuable. It certainly is not sufficient to be a primary log source. It is background. A Space loggie should have a strong background in ACQ (sic) as well as lots of AFSC experience. This would allow him/her to relate to/with space types."

Respondent 002:
"This type of course would be consistent with that given to the aircraft logisticians. It is impractical to ask for someone to support a system without knowledge of what it is that's being supported."

Respondent 003:
"Agree that there should be some type of course that provides an incoming logisticians with an appreciation of the space environment. Also believe basic logistics courses should recognize that the space medium exists and address those aspects of space that impact on logistics in their curriculum. We need to expand existing logistics education to include space and not develop new space logistics education."

Respondent 006:
"Training insufficient because 'hands-on' of space operations essential to understanding different space environment. Operational constraints must be understood to assure effective logistics support."

Respondent 008: Did not answer this question.

Respondent 009:
"Think they also need training in space environmental conditions that impact the logistics problem."

General Comments Question 2:

Respondent 001:
"No. Space log is normal log tailored to a different environment."

Respondent 002:
"Yes, a two to three week course on the peculiarities of logistics support for space is all that is needed. Any competent logistics specialist would then have sufficient background to provide appropriate support."

Respondent 003:
"Yes. Space segments (launch, space, control, user) and their respective functions. Mission of space systems. Existing space systems and functions. Support infrastructure. On-orbit maintenance and servicing concepts."

Respondent 006:
"Yes - to develop understanding of how much a budding space logistician doesn't know."

Respondent 008:
"Yes. Topics: systems, orbits, interfaces, ground systems, C squared."

Respondent 009:
"I think it should be in the graduate school area rather than PCE. It is very difficult to maintain the instructor talent in PCE."

General Comments Question 3:

Respondent 001:
"No. But space log should be integral to space ops."

Respondent 002:
"I do not feel that a separate graduate degree for Space Logistics is a good idea. Until the concept that logistics for space is different than logistics for everything else has been eliminated, space will continue to have problems."

Respondent 003:
"No, not necessarily. Do not see a strong need for that type of specialization -- especially since the personnel system would not recognize it. A loggie is a loggie is a loggie. Would strongly urge AFIT to include a course in space logistics in its masters curriculum and make it part of the core curriculum."

Respondent 006:
"Yes for above reasons of gaining an in-depth understanding of space operations environment and constraints."

Respondent 008:
"No. Graduate programs are not where technical training should be provided."

Respondent 009:
"Yes."

TOPIC V: Future Requirements

General Comments Question 1:

Respondent 001:
"Launch/Launch/Launch!!! Until the launch segment gets under the control of the pragmatic loggie, we won't be able to afford the rest of the system. New tech (sic) is not as important as new thought processes and perceptions."

Respondent 002:
"Do not agree with statement."

Respondent 003:
"I disagree with your statement that the Air Force is trying to find a mission for space. I believe there is a very clear definition of the space mission. There are numerous problems with that mission such as the negation aspects with no capability to perform the mission. The main problem resides in how that mission is going to (be) accomplished. The R & D community does not want to let go. Also, the vulnerability of space assets is in doubt since we do not have a negation capability. This doubt is demonstrated when other wartime CINCs do not expect to rely on space assets to perform missions in wartime that they routinely perform in peacetime. I have attached Annex C to the DRAFT USSPACECOM Space Logistics Master Plan for your info (see Appendix H). This Annex highlights some of the critical technologies that must be exploited to support on-orbit maintenance and servicing."

Respondent 006:
"Autonomous on-orbit satellite servicing systems are developing technology with capability to enhance logistics operations and to make space logistics cost effective."

Respondent 008:
"Disagree. Missions in space are better known than trying to find a 'mission for an airplane'."

Respondent 009:
"See my book."

General Comments Question 2:

Respondent 001:
"Badly - Air Staff does not care AF/LE not manned in Space arena XO and AQ large contingents. AFSC/AFLC don't care."

Respondent 002:
"If the AF allows the growth of the AFLC Det 25 into a Space Logistics Center it will meet the challenge."

Respondent 003:
"This question is very difficult to answer. Action is underway to establish a normalized logistics infrastructure. The PACER FRONTIER initiative is a significant step forward; however, it cannot lose momentum. A space logistics infrastructure will require an investment during a time that resources are in very short supply. PACER FRONTIER is an easy target when the operational benefits will not be realized for years to come. PACER FRONTIER came about because of personalities like General Hansen and Maj Gen Cassity who believed space system support had to be integrated into a more normalized infrastructure if the operational requirements of the warfighting CINC were to be met. Are we prepared -- no. Are we moving in the right direction -- yes. Can we get there -- yes, but there are a lot of variables and a lot of obstacles."

Respondent 006:
"Unable to answer question."

Respondent 008:
"Poorly. Cadre of experts not formed."

Respondent 009:
"They are not, for the space segment."

General Comments Question 3:

Respondent 001:
"No. See 2." ("Badly - Air Staff does not care AF/LE not manned in Space arena XO and AQ large contingents. AFSC/AFLC don't care.")

Respondent 002:
"Not currently, however, I feel that only minor changes are needed to rectify the situation."

Respondent 003:
"Not exactly, but there is not that much that needs to be done. Educate logisticians about space. Expand logistics curricila to include space. Until a cadre of knowledgeable logisticians is established, modify assignment policies to assure top notch high caliber individuals are retained in the space logistics business."

Respondent 006:
"Unable to answer question."

Respondent 008:
"No. Not enough training or emphasis."

Respondent 009:
"Not current enough on space logistics training to comment."

General Comments Question 4:

Respondent 001:
"Correct thoughts and manning in 2 above." ("Badly - Air Staff does not care AF/LE not manned in Space arena XO and AQ large contingents. AFSC/AFLC don't care.")

Respondent 002:
"PCE courses, similar to those given for other specialties would be sufficient. The largest step was the realization that there is a need for logistics in space."

Respondent 003:
"Same as para 3 above. ("Not exactly, but there is not that much that needs to be done. Educate logisticians about space. Expand logistics curricila to include space. Until a cadre of knowledgeable logisticians is established, modify assignment policies to assure top notch high caliber individuals are retained in the space logistics business.")

Respondent 006:
"Assure widespread hands-on operational experience."

Respondent 008:
"Recognize and advocate role of logistics for space systems."

Respondent 009:
"Graduate level training similar to the space operations course would be most helpful."

General Comments Question 5:

Respondent 001:
"Poorly - inherent conflict open vs. closed, central mgt (sic) vs. no mgt (sic). Bad waste of funds with . . ." (respondent did not complete the sentence)

Respondent 002:
"There is significant conflict between the roles of DoD and NASA."

Respondent 003:
"I believe the individual roles are defined adequately; however, I would not say they are working together toward the mutual benefit of the USA. NASA has done their own thing and DoD has done their own thing. There has been very little cross flow in the past. I believe this may be changing to some extent in the supportability arena. There have been some joint ventures and there is significant cooperation between NASA and SSD/ALI on on-orbit maintenance and servicing. I would not go so far as to say this is a mutual admiration society, but there are elements within the respective organizations that are moving together in the spirit of cooperation."

Respondent 006:
"Roles can not be generalized. Missions are different. DoD and NASA should cooperate and compliment needs of each other's mission, supplementing mission unique requirements, capabilities and hardware where necessary. Interface standards for serviceable space craft and on-orbit robotic service systems should be established where possible. Exchange of personnel and training should encourage and develop cross fertilization."

Respondent 008:
"Adequately defined (by law). Some conflict in goals and priorities."

Respondent 009:
"No, the two roles have entirely different focuses, therefore, they have never worked well together. No way to change the situation."

General Comments Question 6:

Respondent 001:
"Both the user and control segments are already separate. The user segment is controlled the same as any comm-elec (sic) equip."

Respondent 002:
"If the continued expansion into space is to be successful, the user segment must be allowed to expand separately. The greater demand for these items the better for space overall. There is no more need for the user segment to be controlled with the other 3 than there is for a radio station to control personnel radios."

Respondent 003:
"To some extent yes, the user segment is treated as a separate entity. User segments are treated and logistically supported as components of the primary system in which they are installed. For instance, the GPS user set in an aircraft is a piece of avionics equipment. I doubt that this will change any time in the near future; however, the primary weapon system (user) must understand that unilateral changes to a piece of installed equipment cannot be made. The impact on the space segment must be understood. This must be the role of the AFLC space system manager -- system engineering. I also believe that the support of the ground user equipment as well as the control segment is being treated as communication - ADP equipment and being integrated into the logistics infrastructure as such. A systems approach to include all segments) to space system logistics management must be implemented if we expect to normalize space system logistics support. A normalized logistics infrastructure will ensure the most effective and efficient support to the operational requirements of the warfighting CINC.

Respondent 006:
"Unable to answer."

Respondent 008:
"Should not be separate from other segments. Needs to operate mutually dependent roles and objectives."

Respondent 009:
"It should not be separated. The user segment has to have involvement in the other segments if they are to get their requirements satisfied. If they are not involved they will never know the full extent of the capability that can be provided."

General Comments Questions 7 and 8:

Respondent 003:
"I need to explain the perspective I used in responding to the above. The support system is doing an excellent job of maintaining the existing space systems on-orbit. Maintenance of the space vehicle is performed through TT & C. That is the way the system was designed. This is not to say that there is not a more efficient and effective way to maintain the space system. Contractor support of the launch infrastructure is excellent but it cannot be responsive to the operational needs of the warfighting CINC. The control segment has a long history of meeting the operational needs of the existing infrastructure; however, as with the launch and space segments technical data per se does not exist. It would be extremely difficult for real competition to exist in these services with the data currently available. I do not see any significant changes occurring between now and the year 2000. Fielding of a Strategic Defense System (SDS) has the potential for initiating a significant change. The potentially large constellations will force a different approach to space system support. On-orbit maintenance and servicing will not only be feasible but be a economic necessity. It would be totally impractical to to use an abandon and replace concept for the Space Based Interceptor. Studies on the Space Surveillance and Tracking System have proven that on-orbit maintenance and servicing is a cost effective alternative. If SDS is not fielded, I believe business will continue as usual. There is a complete lack of interest (or maybe I should say total resistance) from the space system designers. Also, the cost of an on-orbit maintenance and servicing infrastructure will be substantial. No one program office will be able to carry the burden of that cost. We come to the question of what came first, the chicken or the egg? Satellite designers will not design for on-orbit support because a capability does not exist. A capability for on-orbit support is not being developed because a requirement does not exist. The key remains SDS. If the space systems are fielded as projected, on-orbit support should become a reality.

For the launch segment, change will not occur until the Advanced Launch System is fielded. This system and its payload interface must be designed to be supported at the technician level vice engineer level. Launch processing must be simplified to the maximum with significantly reduced pad turnaround times.

The control segment poses a significant vulnerability to warfighting requirements. Satellites must become more autonomous with reduced reliance on foreign-based TT&C. Warfighting system control must move to support from mobile systems for survivability. If and when this happens, portions of the control segment will move from contractor support to organic support. At this point, technical data, maintenance training, etc will all become a necessity."

Additional Comments:

Respondent 006:
"Development of space logistics capability is a long term program which needs to be stated now, as a policy. The NASA - SDIS joint satellite service system flight demonstration with its 3rd flight in 1995 will demonstrate supervised autonomous on-orbit refuel and orbital replacement unit exchange. An operational system will still be at least 10 years later, in 2005. This timeframe provides a window for Air Force logistics to work with program managers to assure development of complimentary spacecraft which are serviceable, and an operational service system."

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY
WRIGHT-PATTERSON AIR FORCE BASE OH 45433-6583

Appendix E: Round Two Delphi Survey

Colonel George J. Sawaya
SM-ALC/MMB
McClellon AFB, Ca 95652-5609

Dear Col Sawaya:

Thank you for completing the first round of the AFIT Delphi survey on space logistics. Your opinions and comments were of great value to this research.

The second round Delphi questionnaire containing respondent feedback is attached. I am certain you will find the comments from our other experts interesting. Please read the comments and then answer the questions that follow. You will notice that the feedback provided for each question includes the mean ratings for all of the experts, plus your response on the last Delphi questionnaire.

I appreciate the time you are investing in this research. Please try to return your completed survey within one week.

You comments, suggestions, and ideas regarding this research are welcome and encouraged. All responses will be treated as confidential and anonymity will be maintained. If you have any questions about this survey please call me collect at (513) 252-2564, or Autovon 785-6569. Thank you for making time to share your expertise.

STEWART G. CARR, Capt, USAF
Air Force Institute of Technology
School of Systems and Logistics

2 Atch
1. Delphi Survey
2. Return Envelope

Round Two Delphi Survey

1. Definitions

a. Military Logistics: A fully integrated system of processes which must be used to support the military operations of an organization, including combat. Although recent logistics doctrine changes this includes all areas which support combat, this survey is directed toward space logistics, if there is such a thing.

b. Space Logistics: Because of the uniqueness of space operations, the definition of military logistics must be applied across the four segments of space operations. Space logistics must be a fully integrated system of processes which must be used to support space operations in the launch segment, the space segment, the control segment, and the user segment.

c. Launch Segment: The launch segment inserts spacecraft into orbit or elsewhere in the space medium and should include getting the satellite to the launch pad and the process required to land and turnaround a reusable transportation vehicle.

d. Space Segment: The space segment includes on-orbit operations and servicing of the spacecraft or satellite.

e. Control Segment: The control segment is the ground based link to the satellite that controls its movement and receives information about the satellites position. The three main functions of the control segment are telemetry, tracking and communications.

f. User Segment: The user segment operationally interacts with the space segment to give utility to operations. The logistics of the user segment is primarily the number and information requirements of the user and the standardization of software and hardware to minimize maintenance problems.

3. General Comments:

a. During this second round you will be given the mean or modal response for all experts and your last response for each question. This feedback is designed to stimulate your thought process as you rethink each question. You will have space to make comments regarding this feedback.

b. Some questions do not need further examination because there was strong expert agreement on the answer. For those question you will be provided with the consensus responses and the percentage agreement.

c. Your participation and honest opinions are key to the success of this research project. There are no right or wrong answers. Therefore, all your ideas and brainstorming comments should be included.

d. Many of the questions call for an answer along a scale. Others ask only for your personal comments.

e. The number in the upper right-hand corner of the questionnaire is for survey control purposes only. Please be assured that complete anonymity will be enforced.

4. Specific Instructions:

a. When a question calls for an answer along a scale, please circle the number which most accurately reflects your judgment on that question or statement.

b. Please write the rationale for your answers, especially for those areas where you feel strongly. Add any illustrations, examples, or experiences you have had that will help the other participants understand your response. Feel free to continue your comments on the back of the survey sheets. Please number your comments so they correspond to the question you are answering.

c. Any ideas or recommendations you have for improving space logistician development should also be included with your responses. Your ideas will be shared with others who care about space logistics and space logistician development.

d. The last page of this survey is for additional comments you feel are pertinent to this study.

THANK YOU FOR PARTICIPATING IN THIS SURVEY.

TOPIC I: SPACE LOGISTICS

1a. Interviews conducted for this research, indicate that space logistics is no different than any other area of logistics. Would you:

Round 1 mean: 2.83 Your round 1 response:

COMMENTS:

RESPONDENT 001:
"It is different because we have not been involved with this arena. Hence, we as loggies don't understand the subtleties of the culture - logistics is logistics, it's the politics and language we need to learn. The basic logistics is unchanged."

RESPONDENT 002:
"Some processes such as contracting and provisioning must proceed at an accelerated pace, but the basic logistic requirements are the same."

RESPONDENT 003:
"Currently space logistics is considered to be different by the development and acquisition community. This mentality probably evolved because for many years the developer, acquisitions agency, operator, and supporter of space systems was one and the same--the research and development community. As space system control moves out of the R & D environment and is assimilated into the operations community, a more traditional approach to logistics is evolving. While this evolution has been slow it continues but with strong reluctance from the R & D community. Logisticians recognize that the basic logistics principles are essentially the same and apply the air, land, sea, and space. However, the operational environment of space is very difficult. Space logistics concepts must be developed that compensate and adapt to this environment. While the same argument can be made for the differences between air, land, and sea, space presents unique challenges to the logisticians."

RESPONDENT 006:
"Space logistics differs from other areas because operating environment differs from earthbound by (1) lack of gravity, (2) thermal, (3) structural, (4) planning constraints, and (5) orbital, (6) mechanical considerations. Space logistics requires an in depth understanding of these differences, will preclude wrong assumptions about operations and performance of equipment on-orbit."

RESPONDENT 008:
"Logistics provides support, regardless of the environment."

RESPONDENT 009:
"Only the logistics for the space segment is different. What makes the space segment different is that the environment is difficult to access. This means from the combat operations standpoint, the space power that has the best logistics cap-bility has the upperhand. There is a definite parallel between this issue and British sea power between 1700 - 1900. I suggest you refer to the last two chapters of my book."

Your new response (circle one):

1	2	3	4	5
strongly disagree	disagree	neither agree nor disagree	agree	strongly agree

1b. Why do you feel that space logistics is different/not different from other areas of logistics?

Your further comments on I-1b.:

TOPIC I: SPACE LOGISTICS (continued)

2. Do you feel the current Military Standards are sufficient for space systems or should Military Standards similar to MIL STD 1388-1A and 1388-2A be developed specifically for space systems? Why or why not?

Round 1 consensus: 75% disagree

COMMENTS:

RESPONDENT 001:
"Current standards are sufficient. While I believe space logistics is different, I also believe it is the same at the basic logistics element and using common tailoring techniques will allow one to use most of the existing specs and STDs very effectively."

RESPONDENT 002:
"NO. I am strongly opposed to the development of separate standards for space when small modifications of existing standards is sufficient in most cases."

RESPONDENT 003:
"Military standards need to be established for standardization and commonality among space systems. I am talking about standards for design interfaces such as refueling and electrical connectors. New standards are not required for those standards such as the two you cite, MIL STD 1388-1A and 2A. These standards and all acquisition related standards should be tailored for the specific application."

RESPONDENT 006:
"It is important to develop interface standards between DoD and NASA for on-orbit servicing. Such standards should include orbital replacement unit interfaces between ORU and spacecraft bus, refueling connectors, data and communication protocols and interfaces between operational tools and robotic manipulators."

RESPONDENT 008:
"Don't know."

RESPONDENT 009:
"Not familiar enough with the standards to comment."

Your further comments on I-2.:

TOPIC II: MAINTENANCE AND SUPPORT

1a. Circle your response to the following statement:

Maintenance of on-orbit systems is too costly to be realistic. The Air Force should continue to focus on systems that are extremely reliable and forget about repairing systems already on orbit:

Round 1 consensus: 67% disagree or strongly disagree.

COMMENTS:

RESPONDENT 001:
". . . This area is totally misunderstood and is a vital part of the space mystique. Many spacecraft will never be economical to maintain but with fundamental changes in the thought process tremendous savings can be had - as well as increased reliability and readiness."

RESPONDENT 002:
"On-orbit repair that extends the useful life of a $500M+ system is becoming to be a more logical approach every day. Orbiting robotic spares platforms could repair and restore satellite quicker than a new launch would and could reduce the number of launch ready spares required."

RESPONDENT 003:
"As stated, your statement is correct. It would be unrealistic to pursue repairing existing systems on-orbit that have not been designed for on-orbit repair. Future space systems must be designed for on-orbit maintenance. There is a substantial body of knowledge available that provides conclusive evidence that on-orbit maintenance and servicing is technically feasible and can realize cost savings. Attached is a report prepared for USSPACECOM/J4-J6L by SSD/ALI (see Appendix G) that synopsizes studies which have been performed to assess the technical feasibility and cost effectiveness of on-orbit maintenance and servicing."

RESPONDENT 006:
"Parametric analysis can determine, for a given program, whether or not this statement is true. Many factors such as transportation cost, fuel budget and cost, service cost, . . (unreadable words) are all factors in cost equations. DoD and NASA studies have demonstrated that while a serviceable spacecraft may cost up to 15 percent additional cost, this investment can be recovered in savings from design test, and integration above, prior to launch. Serviceable spacecraft is a realistic future goal."

RESPONDENT 008:
"Cost needs to include all costs including risk of failure."

TOPIC II: MAINTENANCE AND SUPPORT (continued)

RESPONDENT 009:
"The cost effectiveness of on orbit repair is a function of the orbit. Would refer you to many studies done in the 1970's on the space tug for some insight."

Your further comments on II-1b.:

2a. The "one contractor processing" concept for system launches is not in the best interest of the Air Force. The Air Force should have its own organic logistics support for the launch segment. (e.g., routine preflight, postflight maintenance; payload integration; pad maintenance; and launch activities) Would you: (Please circle your response)

Round 1 consensus: 60% agree.

2b. Why do you feel the Air Force should/should not have its own organic logistics support for systems launches?

COMMENTS:

RESPONDENT 001:
"The AF launched the predacessors (sic) of every expendable out there. Once again a thought process change is required."

RESPONDENT 002:
"With the advent of the ALS and the requirement of 10-20 launches per year, organic support will have the repetitive taskings required to become competent."

RESPONDENT 003:
"The current launch infrastructure should continue to be supported as is. It would be too costly and technologically too difficult to establish an organic capability--assuming you mean a blue-suit capability when you say organic. Future launch systems must be designed to be more responsive to the war fighting CINC. Rapid turn-around of launch facilities with reduced launch vehicle processing and integration times must be a design standard. The one-to-one match of launch vehicle to space vehicle must be eliminated. The launch vehicles must be designed to accept any and all payloads thus the requirements for a standardized payload interface design standard. This does not necessarily mean a blue-suit organic capability. It does mean buying the necessary data and support equipment to put launch in a competitive posture and if possible evolve into a blue-suit capability. It does mean assuring that the launch infrastructure can meet was time tasking requirements."

RESPONDENT 006:
"Unable to respond, don't know the Air Force system."

RESPONDENT 008:
"Self-reliance - i.e., need to develop Air Force capability in aftermath of Challenger accident."

RESPONDENT 009:
"The Air Force has historically had difficulty maintaining the talent and experience in its blue suit force to handle the launch segment."

TOPIC II: MAINTENANCE AND SUPPORT (continued)

Your further comments on II-2b.:

----

3. In your opinion, how well is the Air Force doing toward "normalizing" space logistics?

Round 1 consensus: 100% agree that the Air Force not doing enough.

COMMENTS:

RESPONDENT 001:
"AFLC is doing fair but not addressing anything but control and user segment. AFSPACE DIV has no concept of what support is for launch and on-orbit segment. Space Command is starting to understand Ops (sic) control of launch segment and has not."

RESPONDENT 002:
"As long as programs are allowed to continue to claim that they are 'unique' and therefore should not conform, the AF will never be successful. The duplication of effort by SIO and those required of an SPM is an example of the current lack of normalization."

RESPONDENT 003:
"The Air Force is moving, but moving very slowly. The logisticians and to some extent the operator support normalization efforts. The R & D community continues to resist any loss of control over space systems--be that operational or support. Before any significant change occurs, a complete change of mentality must take place. The first must take place in the Pentagon and in the DCS/LE community. Space logistics is given lip service with only part time advocacy dependent upon the level of interest by the action officer. Top-down guidance and policy must be developed and promulgated at the Air Staff level before a significant impact can be made to force the space system developers and acquisition agency from an R & D mentality.

Certain design constraints that consider supportability must be imposed on the developers and acquisition agency similar to that imposed on aircraft developers."

RESPONDENT 006:
"Unable to respond, don't know the Air Force system."

RESPONDENT 008:
"Significant lag considering how long we have been in space."

RESPONDENT 009:
"Think the issue is in doubt. Refer to General Piotrowski's command briefing to view the large doctrinal split between USSPACECOM and AFSC on this issue. The general wants to go to the Soviet model (rapid launch capability, less capable satellites, etc.) rather than the current AFSC approach."

Your further comments on II-3.:

TOPIC III: SKILLS AND QUALIFICATIONS

1a. Interviews conducted for this research, indicate that there are no specific qualifications that space logisticians should possess outside the realm of other logistic disciplines. Would you:

Round 1 consensus: 83% disagree.

1b. What specific qualification, if any, do you feel space logisticians should possess to work with space systems? If none, why not?

COMMENTS:

RESPONDENT 001:
"Tenacious and ability to get along with obnoxious folks. Its a new arena - we are the outsiders and still haven't been accepted in concept or existence."

RESPONDENT 002:
"As with any logistician, field experience is the best teacher."

RESPONDENT 003:
"If you look at the space environment in its totality, there will be most certainly special qualifications required. As there are specialists in aircraft maintenance there will be specialists in on-orbit maintenance and servicing. If however, you are talking as generality, no special qualification should be required. Space education is required, not new logistics education. I will admit that at this time our cadre of knowledgeable space logisticians is very fragile. Our personnel system fails to recognize that we are immature and if space logistics is to 'normalize', a knowledge base of individuals must be maintained. Unfortunately, 'the system' takes highly qualified individuals making a very positive contribution to normalization of space and transfers them to other functions for 'the greater needs of the Air Force.' I believe this is very short sighted."

RESPONDENT 006:
"Understanding of on-orbit operating environment, orbital mechanics, space operations planning templates, launch service and their constraints."

RESPONDENT 008:
"Logistics must relate to environment. Aircraft maintenance officers must understand aircraft systems. Space logisticians must understand space systems. Special identifiers may be required (similar to C - prefix for computer systems)."

RESPONDENT 009:
"For space logistics, the logistician must understand the environment."

Your further comments on III-1b.:

TOPIC III: SKILLS AND QUALIFICATIONS (continued)

2. If the Air Force role in space expands as projected over the next decade, there will be a dramatic increase in the number of logisticians needed to adequately fill requirements. In your opinion, is the Air Force taking proper steps to fill this need? What steps, if any, should the Air Force take to meet this requirement?

Round 1 consensus: 80% agree that the Air Force is not taking proper steps.

COMMENTS:

RESPONDENT 001:
"No. First, the airstaff AF/LE must care enough to put strong, vocal individuals in the space log slot (maybe even make it two slots) then support them. AFLC and AFSC must then establish strong organizations with Maj/Lt Col level mgt (sic) to force it down into the commands."

RESPONDENT 002:
"The current emphasis of identifying the need for space experience in the MAJCOMs has been a significant step for the AF. This type of effort emphasizes the fact that many of the 'unique' space requirements are actually quite common."

RESPONDENT 003:
"NO. The Air Force must first recognize that space is no longer an R & D activity. It must establish the respective roles of the developer-acquisition agency, the operator, and the supporter. It must then develop appropriate policies to implement the appropriate roles. At this time the predominant influence remains the R & D community, who essentially decline to recognize that a supporter other than they themselves exist."

RESPONDENT 006:
"Unable to respond, don't understand Air Force activities."

RESPONDENT 008:
"If Air Force is taking steps, they are not readily apparent. Technical courses in space systems are needed."

RESPONDENT 009:
"Think the major impact will be the deployment of a BMD system in space. I am involved in BMD planning and don't think logistics is being adequately considered."

TOPIC III: SKILLS AND QUALIFICATIONS (continued)

Your further comments on III-2.:

---

3. Have steps been taken to organize the Air Force space logistics infrastructure to match that of the MAJCOMs? What steps, if any have been taken? If none, what steps should be taken?

Round 1 consensus: 100% agree that the Air Force is not doing enough.

COMMENTS:

RESPONDENT 001:
"Slight. DET 25, SM-ALC is a first step - - - but it is out of step with the rest of the AF."

RESPONDENT 002:
"The biggest mistake that Space Command has made was combining the KR and LG into an LK organization. The structure makes even the most simple operations difficult i.e. having maintenance of hardware under one asst DCS, supply under another asst DCS and software under a totally separate unit."

RESPONDENT 003:
"Do not know what you mean by this question. Supposedly, AFSC is performing its traditional role of developer-acquisition agency. AFSPACECOM is the operator, and AFLC is the supporter. From a logistics perspective this has been accomplished to some extent. Most ground segments are supposed to plan for PMRT. The same does not apply to the

space segment. While AFSPACECOM 'flies' the satellite and performs the 'organizational' maintenance function of health and welfare, anomaly resolution is generally relegated to a R & D function. AFLC has no capability--and I do not see any developing through the mid-term -- to perform its traditional system engineering function for the satellite. This function remains with the R & D community. The Air Force needs to get the R & D community out of the support business. Also, the satellite support function is treated like a communication - ADP function in the operating command. Until it is recognized that space support is not command and control and should not be subordinated as a communication-ADP function, a viable responsive logistics infrastructure will be a long time coming."

RESPONDENT 006:
"Unable to respond."

RESPONDENT 008:
"Somewhat. AFLC has designated a lead ALC for space systems. More in terms of identifying and training personnel is needed."

RESPONDENT 009:
"See above." (Think the major impact will be the deployment of a BMD system in space. I am involved in BMD planning and don't think logistics is being adequately considered.)

Your further comments on III-3.:

TOPIC IV: TRAINING

1a. Logisticians interviewed for this research indicate that any training they received for space logistics was primarily in the form of On the Job Training. However, they also indicated that they would like to have, at least, an overview course in space logistics. The following statement comes from one of the interviews, but was supported by others. Circle your response to the statement.

"Training for space logisticians should consist primarily of an overview course on space systems that includes the types of systems, orbits, and ground system/spacecraft interface."

Round 1 mean: 3.00 Your round 1 response:

COMMENTS:

RESPONDENT 001:
"Since space is still 'different' from what most loggies are raised with, a basic primer course such as the Space and Missile orientation course at VAFB or the SSD orientation course is extremely valuable. It certainly is not sufficient to be a primary log source. It is background. A Space loggie should have a strong background in ACQ (sic) as well as lots of AFSC experience. This would allow him/her to relate to/with space types."

RESPONDENT 002:
"This type of course would be consistent with that given to the aircraft logisticians. It is impractical to ask for someone to support a system without knowledge of what it is that's being supported."

RESPONDENT 003:
"Agree that there should be some type of course that provides an incoming logisticians with an appreciation of the space environment. Also believe basic logistics courses should recognize that the space medium exists and address those aspects of space that impact on logistics in their curriculum. We need to expand existing logistics education to include space and not develop new space logistics education."

RESPONDENT 006:
"Training insufficient because 'hands-on' of space operations essential to understanding different space environment. Operational constraints must be understood to assure effective logistics support."

RESPONDENT 008: Did not answer this question.

RESPONDENT 009:
"Think they also need training in space environmental conditions that impact the logistics problem."

Your new response (circle one):

1	2	3	4	5
strongly disagree	disagree	neither agree nor disagree	agree	strongly agree

1b. Why do you feel this type of training would be sufficient/insufficient for space logisticians? What disciplines or areas of expertise do you feel should be provided to space logisticians?

Your further comments on IV-1b.:

TOPIC IV: TRAINING (continued)

2. Currently, Professional Continuing Education (PCE) courses provide additional training for logisticians in a variety of specialties. These courses are provided by the Air Force Institute of Technology and are two to three weeks in length. Should a PCE course be established specifically for space logisticians? Why, or why not? If so, what specific topic(s) should be included?

Round 1 consensus: 67% agree that a PCE course is adequate.

COMMENTS:

RESPONDENT 001:
"No. Space log is normal log tailored to a different environment."

RESPONDENT 002:
"Yes, a two to three week course on the peculiarities of logistics support for space is all that is needed. Any competent logistics specialist would then have sufficient background to provide appropriate support."

RESPONDENT 003:
"Yes. Space segments (launch, space, control, user) and their respective functions. Mission of space systems. Existing space systems and functions. Support infrastructure. On-orbit maintenance and servicing concepts."

RESPONDENT 006:
"Yes - to develop understanding of how much a budding space logistician doesn't know."

RESPONDENT 008:
"Yes. Topics: systems, orbits, interfaces, ground systems, C squared."

RESPONDENT 009:
"I think it should be in the graduate school area rather than PCE. It is very difficult to maintain the instructor talent in PCE."

Your further comments on IV-2.:

TOPIC IV: TRAINING (continued)

3. Currently, the Air Force Institute of Technology offers a graduate degree in Space Operations. Do you feel that a graduate degree, focusing on Space Logistics, would be beneficial to logisticians working with space systems? Why or why not? Should the Air Force Institute of Technology begin such a program?

Round 1 consensus: 67% agree that a graduate level program is not required.

COMMENTS:

RESPONDENT 001:
"No. But space log should be integral to space ops."

RESPONDENT 002:
"I do not feel that a separate graduate degree for Space Logistics is a good idea. Until the concept that logistics for space is different than logistics for everything else has been eliminated, space will continue to have problems."

RESPONDENT 003:
"No, not necessarily. Do not see a strong need for that type of specialization -- especially since the personnel system would not recognize it. A loggie is a loggie is a loggie. Would strongly urge AFIT to include a course in space logistics in its masters curriculum and make it part of the core curriculum."

RESPONDENT 006:
"Yes for above reasons of gaining an in-depth understanding of space operations environment and constraints."

RESPONDENT 008:
"No. Graduate programs are not where technical training should be provided."

RESPONDENT 009:
"Yes."

Your further comments on IV-3.:

TOPIC V: FUTURE REQUIREMENTS

1. The current position of the Air Force, in relation to space missions, can be compared with trying to find a mission for the airplane, when it first appeared. Where do you feel the Air Force should focus its attention to achieve the best utilization of space assets? What new technologies are emerging in the space logistics field?

Non-Consensus Item:

COMMENTS:

RESPONDENT 001:
"Launch/Launch/Launch!!! Until the launch segment gets under the control of the pragmatic loggie, we won't be able to afford the rest of the system. New tech (sic) is not as important as new thought processes and perceptions."

RESPONDENT 002:
"Do not agree with statement."

RESPONDENT 003:
"I disagree with your statement that the Air Force is trying to find a mission for space. I believe there is a very clear definition of the space mission. There are numerous problems with that mission such as the negation aspects with no capability to perform the mission. The main problem resides in how that mission is going to (be) accomplished. The R & D community does not want to let go. Also, the vulnerability of space assets is in doubt since we do not have a negation capability. This doubt is demonstrated when other wartime CINCs do not expect to rely on space assets to perform missions in wartime that they routinely perform in peacetime. I have attached Annex C to the DRAFT USSPACECOM Space Logistics Master Plan for your info (see Appendix H). This Annex highlights some of the critical technologies that must be exploited to support on-orbit maintenance and servicing."

RESPONDENT 006:
"Autonomous on-orbit satellite servicing systems are developing technology with capability to enhance logistics operations and to make space logistics cost effective."

RESPONDENT 008:
"Disagree. Missions in space are better known than trying to find a 'mission for an airplane'."

RESPONDENT 009:
"See my book."

TOPIC V: FUTURE REQUIREMENTS (continued)

Your further comments on V-1.:

----

2. With the anticipated increase in operational systems over the next decade, how well is the Air Force prepared to meet the logistics challenges?

Round 1 consensus: 80% feel the Air Force is not well prepared.

COMMENTS:

RESPONDENT 001:
"Badly - Air Staff does not care AF/LE not manned in Space arena XO and AQ large contingents. AFSC/AFLC don't care."

RESPONDENT 002:
"If the AF allows the growth of the AFLC Det 25 into a Space Logistics Center it will meet the challenge."

RESPONDENT 003:
"This question is very difficult to answer. Action is underway to establish a normalized logistics infrastructure. The PACER FRONTIER initiative is a significant step forward; however, it cannot lose momentum. A space logistics infrastructure will require an investment during a time that resources are in very short supply. PACER FRONTIER is an easy target when the operational benefits will not be realized for years to come. PACER FRONTIER came about because of personalities like General Hansen and Maj Gen Cassity who believed space system support had to be integrated into a more normalized infrastructure if the operational requirements of the warfighting CINC were to be met. Are we prepared -- no. Are we moving in the right direction -- yes. Can we get there -- yes, but there are a lot of variables and a lot of obstacles."

TOPIC V: FUTURE REQUIREMENTS (continued)

RESPONDENT 006:
"Unable to answer question."

RESPONDENT 008:
"Poorly. Cadre of experts not formed."

RESPONDENT 009:
"They are not, for the space segment."

Your further comments on V-2.:

----

3. Do you feel that the Air Force is adequately preparing space logisticians to meet the challenges of these new technologies? Why, or why not?

Round 1 consensus: 100% agree that the Air Force is not prepared.

COMMENTS:

RESPONDENT 001:
"No. See 2." ("Badly - Air Staff does not care AF/LE not manned in Space arena XO and AQ large contingents. AFSC/AFLC don't care.")

RESPONDENT 002:
"Not currently, however, I feel that only minor changes are needed to rectify the situation."

TOPIC V: FUTURE REQUIREMENTS (continued)

RESPONDENT 003:
"Not exactly, but there is not that much that needs to be done. Educate logisticians about space. Expand logistics curricila to include space. Until a cadre of knowledgeable logisticians is established, modify assignment policies to assure top notch high caliber individuals are retained in the space logistics business."

RESPONDENT 006:
"Unable to answer question."

RESPONDENT 008:
"No. Not enough training or emphasis."

RESPONDENT 009:
"Not current enough on space logistics training to comment."

Your further comments on V-3.:

----

4. What do you feel the Air Force needs to do, if anything, to better prepare space logisticians to meet future challenges?

Non-Consensus Item:

COMMENTS:

RESPONDENT 001:
"Correct thoughts and manning in 2 above." ("Badly - Air Staff does not care AF/LE not manned in Space arena XO and AQ large contingents. AFSC/AFLC don't care.")

TOPIC V: FUTURE REQUIREMENTS (continued)

RESPONDENT 002:
"PCE courses, similar to those given for other specialties would be sufficient. The largest step was the realization that there is a need for logistics in space."

RESPONDENT 003:
"Same as para 3 above. ("Not exactly, but there is not that much that needs to be done. Educate logisticians about space. Expand logistics curricila to include space. Until a cadre of knowledgeable logisticians is established, modify assignment policies to assure top notch high caliber individuals are retained in the space logistics business.")

RESPONDENT 006:
"Assure widespread hands-on operational experience."

RESPONDENT 008:
"Recognize and advocate role of logistics for space systems."

RESPONDENT 009:
"Graduate level training similar to the space operations course would be most helpful."

Your further comments on V-4.:

TOPIC V: FUTURE REQUIREMENTS (continued)

5. How well are the individual roles of NASA and the DoD defined? Do these roles work in harmony or are the two in conflict as far as the best interest of the United States is concerned?

Round 1 consensus: 100% feel that the two agencies are not working together and in the best interest of the U.S.

COMMENTS:

RESPONDENT 001:
"Poorly - inherent conflict open vs. closed, central mgt (sic) vs. no mgt (sic). Bad waste of funds with . . ." (respondent did not complete the sentence)

RESPONDENT 002:
"There is significant conflict between the roles of DoD and NASA."

RESPONDENT 003:
"I believe the individual roles are defined adequately; however, I would not say they are working together toward the mutual benefit of the USA. NASA has done their own thing and DoD has done their own thing. There has been very little cross flow in the past. I believe this may be changing to some extent in the supportability arena. There have been some joint ventures and there is significant cooperation between NASA and SSD/ALI on on-orbit maintenance and servicing. I would not go so far as to say this is a mutual admiration society, but there are elements within the respective organizations that are moving together in the spirit of cooperation."

RESPONDENT 006:
"Roles can not be generalized. Missions are different. DoD and NASA should cooperate and compliment needs of each other's mission, supplementing mission unique requirements, capabilities and hardware where necessary. Interface standards for serviceable space craft and on-orbit robotic service systems should be established where possible. Exchange of personnel and training should encourage and develop cross fertilization."

RESPONDENT 008:
"Adequately defined (by law). Some conflict in goals and priorities."

RESPONDENT 009:
"No, the two roles have entirely different focuses, therefore, they have never worked well together. No way to change the situation."

TOPIC V: FUTURE REQUIREMENTS (continued)

Your further comments on V-5.:

----

6. With the anticipation of continued integration of user equipment in strategic aircraft, and multiservice and special government agency role expansion, do you feel that the user segment, of space operations has become separated from the other three segments? Do you feel that it should or should not be separate from the other segments? Why/Why not?

COMMENTS:

RESPONDENT 001:
"Both the user and control segments are already separate. The user segment is controlled the same as any comm-elec (sic) equip."

RESPONDENT 002:
"If the continued expansion into space is to be successful, the user segment must be allowed to expand separately. The greater demand for these items the better for space overall. There is no more need for the user segment to be controlled with the other 3 than there is for a radio station to control personnel radios."

TOPIC V: FUTURE REQUIREMENTS (continued)

RESPONDENT 003:
"To some extent yes, the user segment is treated as a separate entity. User segments are treated and logistically supported as components of the primary system in which they are installed. For instance, the GPS user set in an aircraft is a piece of avionics equipment. I doubt that this will change any time in the near future; however, the primary weapon system (user) must understand that unilateral changes to a piece of installed equipment cannot be made. The impact on the space segment must be understood. This must be the role of the AFLC space system manager -- system engineering. I also believe that the support of the ground user equipment as well as the control segment is being treated as communication - ADP equipment and being integrated into the logistics infrastructure as such. A systems approach to include all segments) to space system logistics management must be implemented if we expect to normalize space system logistics support. A normalized logistics infrastructure will ensure the most effective and efficient support to the operational requirements of the warfighting CINC.

RESPONDENT 006:
"Unable to answer."

RESPONDENT 008:
"Should not be separate from other segments. Needs to operate mutually dependent roles and objectives."

RESPONDENT 009:
"It should not be separated. The user segment has to have involvement in the other segments if they are to get their requirements satisfied. If they are not involved they will never know the full extent of the capability that can be provided."

Your further comments on . -6.:

COMMENTS: Questions 7 and 8

RESPONDENT 003:

"I need to explain the perspective I used in responding to the above. The support system is doing an excellent job of maintaining the existing space systems on-orbit. Maintenance of the space vehicle is performed through TT & C. That is the way the system was designed. This is not to say that there is not a more efficient and effective way to maintain the space system. Contractor support of the launch infrastructure is excellent but it cannot be responsive to the operational needs of the warfighting CINC. The control segment has a long history of meeting the operational needs of the existing infrastructure; however, as with the launch and space segments technical data per se does not exist. It would be extremely difficult for real competition to exist in these services with the data currently available. I do not see any significant changes occurring between now and the year 2000. Fielding of a Strategic Defense System (SDS) has the potential for initiating a significant change. The potentially large constellations will force a different approach to space system support. On-orbit maintenance and servicing will not only be feasible but be a economic necessity. It would be totally impractical to to use an abandon and replace concept for the Space Based Interceptor. Studies on the Space Surveillance and Tracking System have proven that on-orbit maintenance and servicing is a cost effective alternative. If SDS is not fielded, I believe business will continue as usual. There is a complete lack of interest (or maybe I should say total resistance) from the space system designers. Also, the cost of an on-orbit maintenance and servicing infrastructure will be substantial. No one program office will be able to carry the burden of that cost. We come to the question of what came first, the chicken or the egg? Satellite designers will not design for on-orbit support because a capability does not exist. A capability for on-orbit support is not being developed because a requirement does not exist. The key remains SDS. If the space systems are fielded as projected, on-orbit support should become a reality.

For the launch segment, change will not occur until the Advanced Launch System is fielded. This system and its payload interface must be designed to be supported at the technician level vice engineer level. Launch processing must be simplified to the maximum with significantly reduced pad turnaround times.

The control segment poses a significant vulnerability to warfighting requirements. Satellites must become more autonomous with reduced reliance on foreign-based TT&C. Warfighting system control must move to support from mobile systems for survivability. If and when this happens, portions of the control segment will move from contractor support to organic support. At this point, technical data, maintenance training, etc will all become a necessity."

ADDITIONAL COMMENTS.

RESPONDENT 006:
"Development of space logistics capability is a long term program which needs to be stated now, as a policy. The NASA - SDIS joint satellite service system flight demonstration with its 3rd flight in 1995 will demonstrate supervised autonomous on-orbit refuel and orbital replacement unit exchange. An operational system will still be at least 10 years later, in 2005. This timeframe provides a window for Air Force logistics to work with program managers to assure development of complimentary spacecraft which are serviceable, and an operational service system."

Appendix F: Round Two Delphi Comments

Topic I: Question 1.

Respondent 001:

I'm saying that it is different. What I'm saying is the logistics used to accomplish the task is no different. However, the political environment that we have to operate in is so radically different, that . . . (interrupted). Now, when I say the environment, I'm not talking the physical environment. Physical (environment) requires tailoring of logistics principles. I'm sorry, I don't see that that makes space logistics different.

Respondent 002: (Synopsis of discussion, tape not working)

I still believe that a loggie is a loggie, regardless of the environment. It is just that the "screw driver is exceptionally long for on-orbit maintenance."

Respondent 003:

The functional disciplines that you use in logistics, you still apply. That point I won't change. I think I wrote what I felt in the first one. I was looking at it that, I didn't count difference as being the environment. If you are using the term difference to mean the fact that it is different because you are operating in a different environment, then yes I would agree that it is different. It all depends on how you are using the word.

Respondent 006: I feel very strongly about that. (First round response). Only because, my experience goes back to a lot of service and parts support for construction equipment with Caterpillar and I've done a lot of other things in government. I'm familiar with capital equipment and I feel strongly, that if one doesn't understand the nature of the aerospace business and the nature of the problems of operating in space and in microgravity your probably going to make some severe errors from a logistics standpoint. So that is why I say that a guy who is doing space logistics has to have a fundamental understanding of the differences between operating on-orbit and operating on the ground.

Respondent 009: O.K. Basically, I agree that it is different because of the environment, for the space segment. The political thought, that one kind of escapes me. I don't know if I could agree with that. As far as it being the same logistics principles, I guess that might be true if you got way up to the big principles, maybe not. I guess my thought is you have to make those systems that you put out there accessible. That is the big difference, they are not. There is an issue. Can you ever make some of them accessible? I guess I would have trouble with the statement that they are the same principles.

TOPIC IV: Question 1.

Respondent 001: (Synopsis of discussion, tape bad)

I have trouble understanding what they mean by "hands-on" operational training . . . I do not feel that what he refers to as hands-on training should be required for space logistics, any more than an aircraft maintenance officer should learn how to fly the aircraft he works on.

Respondent 002: (Synopsis of discussion, tape not working)

I agree that training, with an overview course is sufficient, but I still believe there is an advantage to "hands-on" training from the operations standpoint.

Respondent 003:

Rather than making space unique, if in fact we are looking at a generalized logistician, then he should have an appreciation for all of the potential environments, and all of the potential kinds of force structures that he may have to operate in.

Respondent 006:

That is sort of reinforcing what I said earlier. I know that in the Air Force you move people around and guys have two or three year assignments and I know that theoretically a manager can manage anything regardless of where you put him. However, I don't know how you get the in depth understanding of the difference between space operations and ground operations in just sort of a survey course. You have to have some sort of a rotational experience where you are working , I don't know, the integration of space craft, safety question, (and) on-orbit operations. It is a little bit like making love, you can read all the books you want, until you've been there you don't understand it. Maybe that's not the right context, but I think you understand what I mean.

Respondent 009:

I've taught those kinds of courses. The overview kind of thing. I guess I've always been dissatisfied that you could give somebody enough that they understood the problem. I have seen the folks that have come out of the space operations course, I guess that is taught at Wright-Pat, and I've been very impressed with the way the Air Force has upgraded their space personnel by using that course. I would think you would need a similar thing for space logistics. I'm not that familiar with your logistics course at AFIT. I would think that you would almost have to have at least a minor in space logistics.

APPENDIX G: Synopsis of On-Orbit and Servicing Studies

DEPARTMENT OF THE AIR FORCE

HEADQUARTERS SPACE DIVISION (AFSC)
LOS ANGELES AIR FORCE BASE, PO BOX 92960
LOS ANGELES, CA 90009-2960

02 JUN 1989

SSD/ALI

On-Orbit Maintenance and Servicing Studies

USSPACECOM J-4/6L (Col. Kubecka)
Peterson AFB, CO 80914-5003

1. Enclosed are synopses of on-orbit maintenance and servicing studies which have been performed to assess the technical feasibility and cost effectiveness of accomplishing satellite maintenance and servicing operations in space. The studies have addressed a number of on-orbit support concepts including: the use of space-based support platforms (SBSPs) which access the satellites through nodal regression, SBSPs which are coorbital with the constellation, ground-based direct insertion concepts, and the traditional abandon and replace strategy.

2. In general, these studies have concluded that on-orbit maintenance and servicing is technically feasible and no technology breakthroughs are required. Maintaining and servicing satellites on-orbit versus replacing upon failure can realize cost savings ranging from 10 to 50 percent. The amount of savings actually realized is highly dependent on the constellation size and location, spacecraft reliability, required operational availability, and on the assumptions used in the analysis.

3. In addition to cost savings, it has been found that an on-orbit servicing capability significantly enhances the flexibility available to the user through such options as extension of spacecraft service life and survivability through such actions as refueling and replenishment of consumables, and incorporation of technology upgrades through exchange of orbital replacement units (ORUs).

4. Also enclosed are descriptions of support concepts and support assets referred to throughout these study synopses. Although not yet officially approved by SDIO, the descriptions will assist the reader in better understanding the enclosed synopses.

Neal Ely

NEAL M. ELY, Major, USAF
Technical Director
SDI Logistics

2 Enclosures:

1. Study Synopses
2. Descriptions

TITLE: In-Space Servicing of a DSP Satellite

AUTHOR: TRW

DATE: March 1974

DESCRIPTION: A study performed by TRW to determine feasibility and cost effectiveness of on-orbit support for the DSP constellation.

CONCLUSIONS: The study concluded that DSP satellites can be designed to be serviceable on-orbit by automated servicer units. The required design approach differs from current day practice but does not require extension of the state-of-the-art for their implementation. A net program cost savings of 22 percent may be realized through on-orbit support.

TITLE: DSCS II Servicing Study

AUTHOR: TRW

DATE: March 1975

DESCRIPTION: This study was performed by TRW to determine the feasibility and cost benefits of on-orbit servicing for the DSCS II constellation. The support scenario assumed the use of the shuttle and an OMV type vehicle.

CONCLUSIONS: Expendable satellites are cost effective when availability requirements are low but costs increase rapidly as availability requirements increase. On-orbit servicing is most effective when high availability is required and competitive at lower availability requirements. Retrieval and ground refurbishment is not cost effective.

TITLE: USAF Spacecraft Maintenance Policy Review, Volumes I and II

AUTHOR: Adhoc Study Team/HQUSAF/RD/XO/LE

DATE: June 1984

DESCRIPTION: The purpose of this study was to review existing data from within DoD, NASA, and industry to determine if USAF should pursue spacecraft maintenance. The report is in two parts: Volume I includes items of primary concern to management and Volume II provides background material. Volume I looks at historical perspectives, and perceptions versus realities. An analysis of spacecraft maintenance was conducted in which items such as mission derived requirements, maintenance functions, design considerations, benefits and costs, models/analytical techniques, and potential program impacts were examined in depth.

CONCLUSIONS: It is recognized that on-orbit spacecraft maintenance would dictate a coincidental increase to the risk threshold, but it is speculated that in most, if not all, cases the offsets would favorably endorse this decision. The utility of on-orbit spacecraft maintenance, if accepted and developed within the proper context of space systems, appears to provide the nation flexibility and options previously unavailable. The report recommends that space program managers be required to consider spacecraft maintenance options and justify their selection or non-selection of a maintainable design prior to Milestone I.

TITLE: Space Maintenance

AUTHOR: The Analytic Sciences Corporation

DATE: December 1985

DESCRIPTION: This study discussed the technical feasibility of space maintenance, methodology for accomplishment, and identified current opportunities for space maintenance. In addition, economic analyses were performed to determine the economic feasibility.

CONCLUSIONS: Identified an estimated $4B annual loss in 1982 operational satellites due to the absence of a space maintenance capability. Concludes that a space maintenance evaluation model is required to determine the optimum maintenance strategies and cost effectiveness.

TITLE: Cost Effectiveness of On-Orbit Repair and Servicing of Selected Satellite Programs

AUTHOR: C. Feuchter, H. Gevelhoff, K. Neuman, R. Cyler, W. Price, J Richardson, T. Scarborough, Directorate of Aerospace Studies

DATE: October 1986

DESCRIPTION: This study developed a methodology for comparing constellation maintenance strategies and used this methodology to evaluate on-orbit maintenance for three specific satellite/constellation configurations, Satellite D, DSCS, and GPS. Specifically, this study did not determine if on-orbit maintenance can reduce satellite onboard redundancy or search for situations favorable to on-orbit maintenance. A modified version of Aerospace Corporation's GAP model was used to simulate operations and assess expended assets and an internal cost model was used to cost the results.

CONCLUSIONS: There is no single right strategy; rather, the details of specific situations must be considered. Periodic servicing requirements for repairable satellites tend to reverse observed repair strategy cost advantages. The replace-on-failure and on-orbit maintenance strategies both benefit from reducing transportation cost to low earth orbit, however this does not drive the answer. Cost is especially sensitive to the frequency of technology updates.

TITLE: DSP On-Orbit Maintenance

AUTHOR: TRW/Aerojet

DATE: December 1986

DESCRIPTION: This study addresses the technical feasibility of on-orbit support for DSP satellites. Three support scenarios were investigated; in-situ support at geosynchronous orbits, return to low earth orbit for maintenance, and return to earth for maintenance.

CONCLUSIONS: The study concluded that EVA or telerobotic servicing is feasible and that cleaning of mirrors on-orbit offers high payoff for extending useful sensor life. DSP hardware must be redesigned for on-orbit support. Retrieval to earth or low earth orbit for maintenance is feasible if the OTV with docking subsystem is available

TITLE: Space Assembly, Maintenance, and Servicing Study

AUTHOR: Lockheed Missiles and Space Company

DATE: June 1987

DESCRIPTION: The Space Assembly, Maintenance, and Servicing (SAMS) study was performed under a USAF Space Division contract which was jointly funded by Space Division, NASA, and SDIO. The purpose of the study was to define an alternative to spacecraft replacement by using (SAMS) functions to achieve or extend the mission lifetime, capability, and flexibility of space systems. Where SAMS was determined to be cost effective, the study then attempted to define and establish SAMS capabilities to improve and enhance space systems affordability and operational responsiveness.

CONCLUSIONS: All on-orbit support cases studied were less expensive than the baseline abandon-and-replace case. The biggest influence on cost is the effect of increasing spacecraft reliability. Servicing infrastructure hardware costs were found to be insignificant compared to total life cycle costs.

A product of this study was a Design Concepts Handbook published by LMSC. This handbook presents material on: the requirements for SAMS compatible design concepts; recommended approaches to design concepts, to interfaces between SAMS spacecraft and servicers, and to hardware/tool tasks; examples of these approaches as applied to the SAMS study design reference missions; and reviews and bibliographies of prior and current work on spacecraft servicing and hardware/tools. Additionally, a short summary of cost considerations relating to SAMS design concept development is included, to help spacecraft and servicer designers to anticipate the general cost effects of the various design decisions they must make in development of serviceable spacecraft and the related servicing and support equipment.

TITLE: Space Assembly Maintenance and Servicing Study Final Report

AUTHOR: TRW

DATE: June 1987

DESCRIPTION: The Space Assembly, Maintenance, and Servicing (SAMS) study was performed under USAF Space Division Contract Number F04701-86-C-0032 and jointly funded by Space Division, NASA, and SDIO. The purpose of the study was to define an alternative to spacecraft replacement by using (SAMS) functions to achieve or extend the mission lifetime, capability, and flexibility of space systems. Where SAMS was determined to be cost effective, the study then attempted to define and establish SAMS capabilities to improve and enhance space systems affordability and operational responsiveness.

CONCLUSIONS: Significant conclusions include:

- SAMS is cost effective over a broad range of cost assumptions
- Acquisition costs will be high, which mandates the broadest possible user base, and maximum possible standardization
- There does not appear to be any technological roadblock to SAMS implementation. The enabling technologies have all been identified, and no showstoppers have been found
- The greatest cost effectiveness is achieved when more than one satellite is serviced on each SAMS mission

TITLE: Parametric Analysis of On-Orbit Support for SDI Satellites Compared To Satellite Replacement

AUTHOR: T. O'Brien, J. Burger, Advanced Technology, Inc.

DATE: July 1987

DESCRIPTION: This study was a technical operating report prepared for SSD/ALI under Contract Number F04701-85-C-0136. The history of satellite repair was summarized and a need for on-orbit servicing established. The equipment and technologies required for a space asset support system (SASS) was discussed. A LOTUS 123 spreadsheet model was utilized to analyze the operation and support cost of utilizing the SASS method of support to the more traditional abandon and replace concept for three SDS systems, SBI, SSTS, and BSTS. Average annual failure rates were used to determine the number of repair/replace events and the resources consumed. These failure rates were varied to determine sensitivities. In addition, the cost of extending satellite life through preplanned product improvement (P^3I) was examined.

CONCLUSIONS: Results of the analyses are summarized below:

- SBI
  - As failure rates increase the cost effectiveness of on-orbit support becomes more apparent.
  - A cost savings of approximately $1.75B was realized with an annual average failure rate of 7 percent
  - The cost savings when P^3I was used to extend the service life of the constellation was approximately two to one over replacing the constellation
  - The quantity of launch vehicles required for on-orbit support was lower than for replacement
- SSTS
  - Cumulative O&S costs for the representative SSTS system did not justify on-orbit support but as the annual failure rate increased, the gap was narrowed. (The difference between on-orbit support and abandon and replace at a one percent annual failure rate was $1154M and only $520M when the annual failure rate was increased to three percent)
  - When the system life was extended through P^3I, the cost savings over satellite replacement and redeployment was more than three to one.
- BSTS
  - The cost of on-orbit support for BSTS was shown to be prohibitive

TITLE: Supportability Trade Study for First SABIR Constellation

AUTHOR: Rockwell International

DATE: August 1987

DESCRIPTION: A decision tree was utilized to display various supportability options for the first SABIR constellation. After appropriate pruning of the decision tree was accomplished, three primary options remained: (1) deploy a support infrastructure early and repair spacecraft failures, (2) delay deployment of a support infrastructure to avoid peak costs early in the program and replace failed spacecraft until the support infrastructure is in place and operational, and (3) launch to replace failed spacecraft. Trade studies were performed on these three options to determine the most attractive.

CONCLUSIONS: Option One has two attractive features: one, it is the least costly option from a life cycle cost point of view, although its funding tends to overlap SABIR production. Thus, the funding profile tends to be more peaked in the near term in comparison to the other options. Secondly, Option One permits the potential to upgrade the performance capability of the SABIR system as new technologies mature and advanced subsystems are developed early in the system's operational life. The life cycle costs developed for each option are:

- Option One - $24.9B
- Option Two - $37.8B
- Option Three - $41.2B

TITLE: An Analysis of Support Concepts for SDS Satellites (BSTS, SSTS, and SBI)

AUTHOR: T. O'Brien, and J. Burger, Advanced Technology, Inc.

DATE: November 1987

DESCRIPTION: This report documents an analysis performed for SSD/ALI under Contract Number F04701-85-C-0136, Subcontract 934-86-49. A prototype version of the Comprehensive Operational Support Evaluation Model For Space (COSEMS) was used to determine resource consumption and achieved operational availability. The operation and support of the BSTS, SSTS, and SBI constellations, as described in the SDS system concept paper of August 1987, was simulated. Three support concepts were analyzed: space-based support using nodal regression, space-based support with a coorbital infrastructure, and ground-launched replacement of failed satellites. Measures of merit included operation and support costs, determined through the use of a LOTUS 123 spreadsheet model, and achieved operational availability (A_o), determined through COSEMS. Average constellation A_o is determined by COSEMS through the following equation:

$$\text{Mean } A_o = MTBM/(MTBM + MDT)$$

Where,

MTBM = mean time between maintenance
MDT = mean maintenance downtime

CONCLUSIONS: This analysis supports strong consideration of implementing an on-orbit support concept, especially for the highly populated SBI constellation. On-orbit support for SSTS resulted in significant cost savings at annual failure rates higher than three percent. On-orbit support for BSTS results in a small savings if the annual failure rate is five percent or higher. All three concepts were able to sustain a high operational availability. Some constellation specific observations follow:

- SSTS
  - All three support concepts were able to maintain operational availabilities from 0.96 to 1.0
  - The nodal regression and ground replacement concepts required significantly less weight to be launched to orbit than the coorbital approach.
  - At a one percent average annual failure rate, the replacement concept is most affordable (approximately $1B savings). As the failure rate increases, the costs associated with replacement rise dramatically. A three percent failure rate results in an approximate $1B savings for on-orbit support and a savings of $6B results from a seven percent failure rate.

- BSTS

  - Both the coorbital and the replacement concepts maintained nearly a 100% operational availability. Nodal regression was not simulated because of the orbital location.

  - Ground replacement required less weight to orbit by approximately 175K pounds

  - For the three percent failure rate, the O&S costs for the replacement concept were approximately $0.25B lower than for the coorbital approach.

  - At a five percent failure rate, the O&S costs associated with the coorbital concept were approximately $0.5B lower than for the replacement concept.

- SBI

  - All three concepts maintained a high operational availability (.96 to 1.0) with nodal regression being the least responsive.

  - The coorbital concept requires significantly more weight to orbit than nodal regression or replacement. The weight to orbit for replacement nearly equalled that of nodal regression until a seven percent failure rate was reached. At that point it exceeded nodal regression by approximately 0.1 million pounds, 0.3 million pounds at a nine percent failure rate.

  - O@S costs for nodal regression remained at approximately $10B over all failure rates while costs for coorbital and replacement rose from $22B to $30B and $20B to $55B respectively. The static nature of the nodal regression costs are probably due to oversizing the support infrastructure for the lower failure rates.

In support of various studies and briefings, the COSEMS simulations used in this study have been updated several times to reflect the newest architectures and operational requirements. These updated simulations have all yielded similar results.

TITLE: BSTS On-Orbit Maintenance and Servicing (OOMS) Study

AUTHOR: TRW

DATE: 1986/1987

DESCRIPTION: This study examines satellite design features in order to better define candidate critical failures. Near/far-term OOMS scenarios are examined in detail, depicting operations and support infrastructure and identifying BSTS unique support equipment. OOMS cost benefits versus a launch-on-demand satellite replacement strategy were compared. Assumptions enumerated were that near-term OOMS applies to pre-operational satellites stored in low to medium orbits, far-term OOMS can accommodate satellites in low to high orbits. OOMS concepts incorporate near/far-term operational infrastructures.

CONCLUSIONS: The study concluded that launch-on-demand satellite replacement is more cost effective than OOMS in the near term. Far term, in-situ OOMS of failed satellites becomes more competitive with satellite replacement. OOMS will improve upon satellite availability and vulnerability.

TITLE: Satellite Servicing - A NASA Report to Congress

AUTHOR: NASA Office of Space Flight

DATE: March 1988

DESCRIPTION: This report was prepared by NASA in response to a request from Congress to "... conduct a thorough and comprehensive study of satellite servicing with a view toward establishing national goals and objectives for utilizing such capabilities."

CONCLUSIONS: Progressing from a contingency reaction to a baselined activity within many user programs, the intent of servicing is to extend operational life, enhance capabilities, and decrease system life cycle costs. Servicing is currently constrained to shuttle accessible orbits, but it will evolve to include space station based activities and remote operations with robots in support of long term operations in space. NASA proposed that the development of appropriate satellite servicing capabilities to enhance and protect national capital investments in space systems be considered and subsequently adopted as a national goal.

TITLE: Space Repair Cost Estimates for Space-Based Interceptor - Single Best Cost Estimate

AUTHOR: J. Suttle, and T. Jee, Tecolote Research, Inc.

DATE: May 1988

DESCRIPTION: This briefing covers the single best estimate developed for the Space-Based Interceptor Program Office for the Summer 1988 Defense Acquisition Board. Cost estimates for two on-orbit support concepts, ground based, and space based, were developed to compare against the abandon and replace strategy. These concepts were costed with and without transportation costs and with and without a weight penalty for modular satellite design.

CONCLUSIONS: Life cycle savings due to on-orbit repair ranged from a low of \$9.1B to a high of \$15B. The savings realized by the program baseline was \$9.1B.

TITLE: Comprehensive On-Orbit Maintenance Assessment

AUTHOR: C. Feuchter, K. Neuman, K. Sparrow, C. Van Meter, Directorate of Aerospace Studies

DATE: June 1988

DESCRIPTION: The stated objective of this study is "find when it is cheaper to repair satellites than to replace them." Two generic satellites, expendable and repairable, were simulated in a variety of constellation configurations under varying launch to replace and on-orbit maintenance support scenarios. The Aerospace Corporation's GAP model was modified to assess expended assets and an in-house cost model utilized to cost the simulation results.

CONCLUSIONS: The best repair strategy was one which reacts to random failures and anticipates truncation failures. Practical opportunities for saving with repair exist now and will continue to exist, but only for high cost scenarios. A zero to 40 percent total cost savings is possible. Lowering transportation costs to low earth orbit lowers expendable cost faster than repairable cost.

TITLE: On-Orbit Maintenance Study, Phase I Final Report

AUTHOR: ANSER Corporation

DATE: August 1988

DESCRIPTION: This study was sponsored by AF/LE under Contract Number F49642-86-C-0161. The study looked at three constellations and evaluated the feasibility of performing on-orbit maintenance. The programs and concepts evaluated are:

- o DMSP using ground-based on-orbit support via ELV or shuttle
- o GPS using coorbital space-based support platforms (SBSP) and SBSPs supporting multiple satellite rings through nodal regression
- o BSTS with a collocated SBSP

CONCLUSIONS: Results indicated very strongly against on-orbit maintenance for DMSP; on-orbit maintenance not cost effective for GPS; and a marginal benefit for BSTS. The key driver against on-orbit support for these systems was the lack of economy of scale for the small constellations. These results are not applicable to the satellite rich SDIO constellations such as SBI. A separate study will be needed to clarify the potential for SBI on-orbit support cost effectiveness.

TITLE: AIAA Assessment of SDI Technologies

AUTHOR: American Institute of Aeronautics and Astronautics

DATE: September 1988 (Draft)

DESCRIPTION: The AIAA reviewed and assessed the technologies involved in the research, development, and deployment of strategic missile defense systems. The assessment is organized into four sections corresponding to the SDI program elements and a fifth section to address support systems. In each section, the technological issues that must be resolved to deploy a credible Strategic Defense System (SDS) are defined and actions to resolve them are proposed.

CONCLUSIONS: A key finding was that on-orbit servicing and maintenance will be needed for deployed operational phases of the SDS. On-orbit servicing offers a technique for extending service life and thus the potential for reducing life cycle costs. In addition to extending service life, on-orbit servicing can also enhance the operational flexibility. The key issues in providing a servicing capability are both engineering and programmatic. The engineering issues include the development and demonstration of autonomous rendezvous and docking capability; fluid thermal and electrical connectors; fluid transfer technology; and built-in test and diagnostics. The programmatic issues are those that require management commitment with appropriate policies and program plans that extend into the future. These include the implementation of new spacecraft design practices that make components accessible and serviceable, the development of standardized hardware and software interfaces, and planning for a support infrastructure that extends into space.

TITLE: Cost Effectiveness of On-Orbit Servicing for Large Constellations
AIAA/SOLE Second Space Logistics Symposium

AUTHOR: W. Robertson, J. Sliney, J. Luna Dynamics Research Corporation

DATE: October 1988

DESCRIPTION: Investigates the cost effectiveness of on-orbit support for large constellations using three alternative support concepts. These concepts are:

- o Launch to replace failed satellites
- o Space-based support utilizing coorbital SBSPs
- o Space-based support utilizing SBSPs to support multiple rings of satellites through nodal regression

The life cycle costs (LCC) for each of these alternatives were calculated as a function of life cycle over the range from five to twenty years. The methodology for comparing LCC included consideration of added redundancy and on-orbit spares. Mean Time Between Critical failure (MTBCF) was varied to provide the most cost-effective design for each support concept.

A spacecraft having an MTBCF of 3.3 years, weighing 400 kg, and costing $50M was used as a baseline against which fluctuations in MTBCF and associated weight and cost changes were measured. The constellation studied consisted of nine rings of twenty satellites each at an altitude of 700 km and an inclination of 85 degrees.

CONCLUSIONS: A slightly higher LCC for the nodal regression concept over the coorbital approach was noted. This higher cost was attributed to:

- o In order to achieve the required 5 yr MTBCF, to match planar alignments, the satellite was 20 percent more expensive
- o The SBSPs utilized were larger and heavier even though they were fewer in number
- o The consumption of OMV fuel was higher resulting in increased launch costs

In either case, the utilization of on-orbit support appears to offer significant cost savings over launch to replace. Possibly as much as 50 percent. It was also noted that one of the most important issues regarding system design and support is the cost of reliability.

TITLE: Optimizing Reliability for SDS Support Cost Effectiveness

AIAA/SOLE Second Space Logistics Symposium

AUTHOR: J. Luna, J. Sliney, W. Robertson Dynamics research Corporation

DATE: October 1988

DESCRIPTION: Proposes a method for comparing life cycle cost (LCC) of a large constellation of satellites for on-orbit maintenance and launch to replace support concepts. A relationship is established between satellite cost and satellite mean time between failure (MTBF), the latter being used as a measure of reliability. The satellite cost versus MTBF relationship is used to compute overall acquisition, support, and life cycle costs. The value of MTBF that minimizes LCC as well as the minimum LCC itself are compared between the two support concepts.

CONCLUSIONS: The on-orbit support concept was shown to be the more desirable of the two concepts considered for two reasons: (1) It is more cost effective in the ranges of satellite MTBF and operational lifetime values proposed; (2) It has less risk because it allows for lower MTBF values and is less sensitive to changes in the achieved satellite MTBF.

TITLE: Space Assembly, Maintenance, and Servicing (SAMS) Study - Independent Mission Cost Effectiveness Assessment

AUTHOR: J. Suttle, T. Jee, S. Stepanek, Tecolote Research, Inc.
R. Curtis, SAIC

DATE: November 1988

DESCRIPTION: This is the first of two reports, performed for Air Force Space Systems Division under Contract Number F04701-87-D-0004, which address the technical requirements and cost effectiveness of performing on-orbit maintenance and servicing on Air Force satellite systems. The second report was entitled "Space Assembly, Maintenance, and Servicing (SAMS) Study - Minimum Investment Satellite Repair and Servicing Analysis. The objective of this first report was to conduct an independent mission cost effectiveness assessment of the concept of space repair and space servicing. This analysis identified trends and break even conditions between the conventional concept of replacing satellites upon failure, versus the proposed concept of repairing satellites on-orbit by roboticaly exchanging failed subsystems. The focus was on current and near term Air Force and DoD satellite systems, not the Strategic Defense Initiative (SDI) weapons or surveillance platforms. However these systems were considered as a subset of the analysis. The issue addressed was whether the Air Force, from the Space Division viewpoint, should consider block changes on its current systems to facilitate the space repair concept.

CONCLUSIONS: The repair/servicing concept can potentially be beneficial to Air Force systems. In general, nominal savings of up to 33 percent and maximum savings up to approximately 50 percent can be realized. Exact savings are dependent on the system analyzed. An investment is required to achieve these savings. If the DoD decides to commit to a servicing infrastructure or maintenance concepts which employ minimum infrastructure elements, many satellite systems would probably adopt the space repair and servicing concept. No one satellite user wants to have the first need (and thus the cost) of infrastructure development. However, the cost savings available, coupled with the mission enhancing capabilities , could lead to a revolution in the way satellite systems are designed, produced, operated, and maintained in the future.

TITLE: Space Assembly, Maintenance, and Servicing (SAMS) Study - Minimum Investment Satellite Repair and Servicing Analysis

AUTHOR: T. Jee, and J. Suttle, Tecolote Research, Inc.
R. Curtis, SAIC

DATE: December 1988

DESCRIPTION: This study is the second of two reports, performed for Air Force Space Systems Division under Contract Number F04701-87-D-0004, which address the technical requirements and cost effectiveness of performing on-orbit maintenance on Air Force satellite systems. The first report was entitled "Space Assembly, Maintenance, and Servicing (SAMS) Study - Independent Mission Cost Effectiveness Assessment." This second report addresses four different maintenance and servicing topics. First, was a comparison of the autonomous on-orbit spacecraft and servicing concept (commonly known as the add-a-pod concept) proposed by Fairchild Space Company to the more conventional maintenance and servicing techniques which use robotic servicers and orbital replacement units (ORUs). In the add-a-pod concept, a replacement module or subsystem is attached to the original spacecraft at an appropriate interface location and the failed components are disconnected via an internal software control system. Second, satellite refueling scenarios were evaluated using the conventional space tanker technique and an add-a-pod concept. Third, an excursion case was evaluated which looked at the possibility of using the add-a-pod technique to recover satellites placed in errant orbits due to upper stage propulsion failures. Fourth, financial analysis procedures were used to assist in the evaluation process of add-a-pod and ORU servicing concepts.

CONCLUSIONS: The major point of the add-a-pod analysis is that potential life cycle cost savings are of greater magnitude than ORU concepts (20 percent compared to 10 percent) without large up-front infrastructure development costs. Mission specific requirements will drive the selection of refueling techniques. If only a limited amount of fuel to a few satell[illegible] is required, it is envisioned that the add-a-pod concept [illegible] single mission tanker would best suit the need. If multiple satellites need to be refueled, a space-based dedicated tanker system could be the most beneficial. The concept of recovering an errant satellite with the add-a-pod technique appears to be technically feasible; however, a more in-depth look at the issues involved is warranted before any recommendations can be made regarding potential benefits of this concept.

TITLE: Space-Based Supportability

AUTHOR: Martin Marietta Denver Aerospace

DATE: December 1988

DESCRIPTION: This document is an IR&D study and is classified as Martin Marietta proprietary. Access is limited to those with a need to know. The report provides the results of an in-depth study of on-orbit repair and servicing of satellites and presents conceptual designs for space-based support platforms and mobile servicing systems.

CONCLUSIONS: This study concludes that the technology to accomplish on-orbit servicing either exists or is on the horizon. An examination of communications requirements and existing technology indicates that linkage from the ground to orbiting vehicles is a solvable problem and is within current capabilities. The use of a teleoperated support system is a feasible approach and technology necessary to implement a video link is available. Many of the transportation and servicing devices required to configure, assemble, and deploy support systems in space are existing or in near term development.

DoD and NASA studies have suggested that for some satellite constellations, the most favorable and cost effective solution to the problem of prolonging satellite life is to deploy and maintain a space-based support system. This will require a great deal of industry and government involvement, prolonged study, and in-depth analyses.

TITLE: Ring Dedicated Support - Special Study #15

AUTHOR: Martin Marietta Denver Aerospace

DATE: December 1988

DESCRIPTION: This special study was performed for the SBI program office under Contract Number F04701-87-C-0064. It is classified competition sensitive and only those with a need to know can gain access. The purpose of the study was to develop and analyze ground based, ring dedicated support concepts for SBI. Five operational scenarios for ring dedicated support were developed and analyzed resulting in selection of one option as most effective. Life cycle cost data were developed, drivers identified, and sensitivities explored. In addition, military OMV parameters were defined and requirements for use of the OMV with the ring dedicated support option identified.

CONCLUSIONS: It was found that all of the ring dedicated concepts developed were comparable in maintenance costs and slightly more costly than a space-based support option utilizing space-based support platforms. In addition, it was concluded that the OMV is a suitable and cost effective vehicle for use with the ring dedicated support option.

TITLE: On-Orbit Study

AUTHOR: T. Parks, E. Sims, Logistics Management Institute

DATE: January 1989

DESCRIPTION: This study was conducted by the Logistics Management Institute (LMI) for the SDIO Phase I Engineering Team (POET). The purpose of the study was to examine the feasibility and cost effectiveness of on-orbit support for the SSTS constellation. Two satellite options were examined, one with a replaceable long wave infrared sensor (LWIR) and one with a nonreplaceable LWIR. A ground-based, direct insertion, on-orbit support concept was compared to an abandon and replace strategy. The prototype Comprehensive Operational Support Evaluation Model for Space (COSEMS) was used to quantify repair/replace events and to calculate achieved operational availability for both support strategies.

CONCLUSIONS: Cost results indicated that O&S costs for on-orbit support of the satellite with the nonreplaceable LWIR sensor were about equal to the costs for the abandon and replace concept. Costs for on-orbit support of the satellite with a replaceable LWIR sensor were approximately 40 percent lower than the cost of abandon and replace. All three options were capable of maintaining an operational availability of .97 to .98.

It was recommended that a modular/serviceable design study be accomplished for SSTS to examine the feasibility of developing a replaceable/repairable LWIR sensor. In addition, it was recommended that an on-orbit servicing strategy for SSTS be adopted.

TITLE: On-Orbit Servicing Cost Estimate for the SBI Program

AUTHOR: T. Jee, Tecolote Research, Inc.
R. Curtis, SAIC

DATE: May 1989

DESCRIPTION: This study utilized the Summer 1988 cost analysis requirements document (CARD) as a technical and cost baseline for comparing life cycle cost for two support options to that of an abandon and replace strategy. The on-orbit support options were a ground-based, ring dedicated concept, and a space-based concept utilizing space-based support platforms capable of serving multiple rings through nodal regression. The key element in this study is that all support options were evaluated using the same ground rules and assumptions. The Comprehensive Operational Support Evaluation Model for Space (COSEMS) was utilized to determine the number of repair/replace events. The Space Assembly, Maintenance, and Servicing Analysis (SAMSA) model was modified to perform the cost analysis.

CONCLUSIONS: This study concluded that there was a cost benefit associated with both servicing concepts. The resulting life cycle cost savings for each of the support concepts when compared against the abandon and replace strategy are as follows:

Nodal Regression	9 percent
Ring Dedicated	4 percent

Satellite reliability and mission performance requirements are the biggest drivers in the selection of a support concept. Satellite reliability determines how many failure events can be anticipated over time and mission performance requirements determine how fast these failures need to be remedied.
The on-orbit infrastructure required for on-orbit repair missions could be used to extend the capability of Phase I SBI assets through preplanned product improvement (P^3I). Extended lifetimes for Phase I assets could allow combinations of Phase I and Phase II assets to maintain overall mission performance levels as a second phase SDI system is deployed. A large portion of the Phase I support architecture could be used to service a Phase II system, negating up front costs of many Phase II infrastructure elements.

TITLE: On-Orbit Support for Phase One

AUTHOR: E. Sims, T. Parks, Logistics Management Institute (LMI)

DATE: May 1989

DESCRIPTION: This study is an update of a similar study performed in January, 1989 by the LMI for the SDS Phase One Engineering Team (POET). The purpose of this study was to determine if there is a minimal on-orbit support strategy (MOSS) for Phase One SDS satellites that is better than "business as usual" (throw away - abandon and replace). This question was addressed from the cost, schedule, technical risk, and program distribution aspects with an emphasis placed on the SSTS system. The Comprehensive Operational Support Evaluation Model for Space (COSEMS) was utilized to determine resource requirements.

CONCLUSIONS: The study concluded that a MOSS for Phase One is financially prudent (a life cycle cost reduction for SSTS of $3.4B was shown), militarily advantageous, contained no technical show stoppers, and is gaining wide support within the community. As a result, the POET recommended that a MOSS infrastructure be developed for SSTS and that SSTS satellites be designed for on-orbit servicing. In addition, it was recommended that an on-orbit servicing strategy be included in SBI phase one and SDS phase two concept design studies.

SUPPORT ASSETS

SPACE ASSET SUPPORT SYSTEM (SASS)
The SASS is a system of unmanned support assets planned to provide cost effective maintenance, servicing, and preplanned product improvement (P^3I) for the space assets of the SDS. The SASS could include any combination or all of the following elements depending on the support concept(s) employed. Space based support platforms, robotic servicers, orbital transfer vehicles, and fluid transfer systems.

SPACE BASED SUPPORT PLATFORM (SBSP)
The SBSP is the center of space based support operations when the nodal regression or coorbital support concepts are employed. It provides thermally controlled storage for satellite ORUs, consumables such as station keeping fuels and cryogens, docking for the OMV, and storage for the robotic servicer and refueler. In addition, the SBSP stores ORUs to support itself and other SASS components.

ORBITAL MANEUVERING VEHICLE (OMV)
The OMV is the transportation vehicle used to move payloads from one location to another. It is the vehicle that carries the robotic servicer and the refueler from the SBSP to SDS satellites and returns them to the SBSP upon completion of the support mission. The OMV may also be deployed coorbitally with a ring of satellites independent of an SBSP.

ROBOTIC SERVICER
The robotic servicer is attached to the OMV. Through the use of robotic arms with end-effectors, and a vision element which includes a video element with illumination, the robotic servicer performs ORU remove and replace operations, routine inspection, space assembly, and corrective repairs. The robotic servicer may receive utilities such as power and thermal protection from the OMV, or from a utility kit which will be a part of the robotic servicer.

ON-ORBIT CONSUMABLE RESUPPLY SYSTEMS
The on-orbit consumable resupply systems are fluid transfer systems capable of resupplying propulsion fuels, such as hydrazine and other fluids. These systems are carried by the OMV and are dependent on the OMV for mobility and support.

ORBITAL TRANSFER VEHICLE (OTV)
The OTV is utilized for servicing and maintenance at high altitude or other high energy orbits. Coupled to an OMV, robotic servicer, or refueler, the OTV provides the necessary energy required for large payloads, long distances, and large plane changes.

ORBITAL REPLACEABLE UNIT (ORU)
An ORU is a component of the satellite which can be removed and

replaced while the satellite is on orbit

ORU CARRIER (ORUC)
The ORUC is a rack attached to the OMV, or other mode of space transportation used in remote servicing, which carries ORUs required for the support mission. The ORUC may at times be an integral part of the robotic servicer. Like the robotic servicer, the ORUC will receive utility requirements from the host vehicle.

RESUPPLY UPPER STAGE
A resupply upper stage is an upper stage that is used during a ground launched resupply mission to accomplish rendezvous with the OMV to transfer resupply items.

ON-ORBIT SPARE SATELLITE
A spare satellite which is placed into orbit, usually during constellation deployment, to be activated when needed.

GROUND LAUNCHED REPLACEMENT SATELLITE
A spare satellite which is launched from the ground into the constellation when needed.

BULK FUEL TANKER (BFT)
The BFT is a tanker based in space to serve as a storage facility for bulk fuels such as OMV propellant, station keeping fuel, cryogens, etc.

SUPPORT CONCEPTS

TELEMETRY BASED REPAIR

Telemetry based repair is that repair accomplished via telemetric command to the satellite. These repairs include such actions as switching in redundant units, software modification, etc.

ABANDON AND REPLACE

Under the abandon and replace concept, failed satellites are replaced with spare satellites. The spare satellites are either launched on demand or placed into orbit at the time of constellation deployment as inactive spares and activated when needed. The term for the latter is proliferation.

SPACE-BASED ON-ORBIT SUPPORT

Space-based on-orbit support requires the deployment of a space-based support infrastructure consisting of elements of the Space assets Support System (SASS). Specific equipment requirements depend on the number of satellites to be supported and the method of accessing the satellites. Two approaches may be used for accessing the satellites: nodal regression and coorbital. The on-orbit support concept may at times be augmented by some combination of other support techniques, such as on-orbit spare satellites, or direct insertion missions as required to maintain the operational availability of the constellation.

Nodal Regression. The nodal regression approach calls for placement of SASS elements in the same or nearly the same orbital inclination as the SDS satellites, but at a higher or lower altitude. This manner of deployment produces a differential nodal regression rate between the SBSP and the SDS assets. This differential regression rate results in periodic alignments of SASS elements and the SDS satellite orbital planes during which support missions may be accomplished by minimum energy transfer of an orbital maneuvering vehicle (OMV) from the SBSP to the SDS satellite orbit to perform servicing or maintenance and return to the SBSP orbit.

Coorbital. The coorbital approach employs SASS elements in each orbital ring of the constellation being supported. The OMV can maneuver to a satellite in the same ring, perform its mission, and return, or it may visit several satellites in the ring before returning.

DIRECT INSERTION ON-ORBIT SUPPORT

When using the direct insertion on-orbit support concept, ground launched support missions are undertaken by launching an OMV, or other equivalent sized vehicle, with the necessary equipment and materials, directly into the SDS orbital ring of the degraded/failed satellite to accomplish the required support. Upon completion of the mission, the OMV can be either left in the ring for future use, deorbited and discarded, or it can be recovered and returned to earth for refurbishment and use in future support missions. If left in the orbital ring, the OMV can be resupplied from the ground with materials to accomplish future support missions within the ring

SUPPORT FUNCTIONS

FAULT DETECTION/FAULT ISOLATION (FD/FI)
FD/FI is a process designed to discover the existence of a fault in the system and to identify the location of that fault, usually to the ORU level.

PRE PLANNED PRODUCT IMPROVEMENT (P^3I)
P^3I is the improvement of a satellite's capability usually accomplished through replacing an ORU with an ORU which contains the upgraded capability or new technology.

RECONSTITUTION
Reconstitution is the process of restoring the constellation to full operational capability after an engagement, or failure of on-orbit spares, to achieve optimum operational capability from the remaining assets until reconstitution can be accomplished. This process could include such actions as relocating satellites, redistributing interceptors, etc.

SPACE BASED SUPPORT MISSION
A space based support mission is a mission undertaken by an OMV based at an SBSP, or a coorbital OMV, to accomplish ORU changeout, consumable replenishment, or other support to a satellite or ring of satellites.

GROUND LAUNCHED SUPPORT MISSION
A ground launched support mission involves the launch of an OMV, complete with the necessary equipment and supplies, directly into the constellation orbit to accomplish a repair or support activity.

GROUND LAUNCHED RESUPPLY MISSION
A ground launched resupply mission is the ground launch of ORUs, OMV fuel, or other consumable items to resupply an SBSP or coorbital OMV.

CRITICAL TECHNOLOGIES TO SUPPORT ON-ORBIT MAINTENANCE AND SERVICING

C.1 CRITICAL TECHNOLOGIES. Most of the technologies required to fly serviceable assets and provide "normalized" on-orbit service by 2000 are available in advanced stages of research and development. In some instances, the technology is well proven in other applications but lacks specific application to the required task or hardware. In most cases, the critical technologies require engineering development rather than achievement of fundamental breakthroughs to deploy reliable, cost-effective, on-orbit servicing assets. These technology needs are discussed below. Most of these items are being developed or can be developed with present technology. Specific engineering to design and demonstrate the items and their technical readiness to the particular system requirements is needed.

C.1.1 On-Orbit Servicing Architecture. On-orbit servicing can be performed only if the space assets are designed to be serviced. This will require the adaptation of a new spacecraft architecture in which the components are located on an external frame where they are accessible instead of being buried within the interior. This architecture must include standard fittings, interfaces, and docking locations.

C.1.2 Automatic Rendezvous and Docking. Initial remote servicing missions using the OMV will be flown under active control from ground terminals. However, the economics and operational flexibility of on-orbit servicing will be greatly enhanced by an autonomous rendezvous and docking capability. This capability would significantly reduce mission support requirements and improve the reliability and repeatability of the docking operation.

C.1.3 Integrated Inferential Test and Diagnostics. On-orbit servicing can be performed most economically if the source of anomalies is known with high precision. Complete instrumentation helps provide this information, but there remains the uncertainty as to whether the error signal results from a true failure or a bad sensor. This uncertainty can be further reduced by measuring the state of the entire system and inferring from the entire set of anomalies the one failure which could be responsible. The basic artificial intelligence techniques are derived from medical applications, and require tailoring to the very system specific applications which will be needed.

C.1.4 Simple Reliable ORU Handler (Robotic). Standardization of docking locations and fittings will allow robotic replacement of ORUs by relatively simple, well-defined motions. This simplicity allows the robotic device to achieve the high level of reliability required to make on-orbit servicing economically viable. It also allows the robotic servicer to be based upon near-term technologies. Highly capable robots with advanced sensing, manipulative, and semi-cognitive capabilities will not be required. The reliability and affordability of the robotic equipment will be of paramount importance.

C.1.5 Standard Data Bus. A standard data bus will not only provide the interface for replacement of components, but will allow for upgrades and new functions to be added in later years. Standardization will allow the same components to be used on many programs. No technology development is required to achieve this, merely agreement upon a standard.

C.1.6 Fluid and Electrical Connectors. Connectors suitable for robotic operation must be developed for fluid and electrical interfaces. NASA has funded the development of a family of space-qualified electrical connectors for space servicing applications. These will meet data and low power electrical requirements, but might need additional development and qualification to meet the requirements of high current electrical bus applications. Robotic fluid umbilical connectors are also being developed. These will require further development in order to meet anticipated weight and reliability requirements. The fluid connectors being developed are for the purpose of transferring fluid from one vehicle to another. Another type will be required to allow components such as valves or pumps in a fluid system to be replaced without introducing either leakage or excessive pressure drop into the line.

C.1.7. Thermal Management. The simplest thermal control for the spacecraft would be achieved by making each ORU thermally independent. However, this is very inefficient and will not be practical in most cases due to power dissipation levels, geometry constraints, or area limitations. A central thermal bus must then be used. Such a system must have the capability of maintaining system temperature within an acceptable range in the presence of widely varying loads as ORUs are removed and installed. Interfaces between ORUs and the thermal bus must be developed. This interface must provide a repeatable, predictable, high thermal conductivity connection which can be broken and reestablished in space.

C.1.8 Fluid Handling. On-orbit resupply of propellants or other fluids can be executed in one of two ways. Fluid can be transferred from the tanks of a resupply tanker into the original tanks of the vehicles being serviced. Alternatively, the old, depleted tanks can be considered as ORUs and removed and replaced with full tanks.

The physics and technology requirements are more stressing for the approach utilizing fluid transfer. Issues related to low-g fluid physics require resolution. More accurate and reliable quantity and quality gauging techniques must be developed, especially for cryogenic fluids.

The transfer of hydrazine, a standard spacecraft propellant, has been demonstrated on-orbit and additional demonstrations are planned. The transfer technology is based upon refilling an expended bladder tank under pressure and then recharging the gas pressurization system used for liquid expulsion. The same technology can also be used with water and similar fluids.

Desire for a higher specific impulse often drives system designers to the use of bipropellant systems. The ability to resupply bipropellant systems will require development of additional technology such as long-life bladders for corrosive materials and demonstration of purge and fill techniques for these substances.

There is a major technology shortfall in the on-orbit resupply and handling of liquid oxygen and liquid hydrogen. The behavior of these materials in low gravity environments is not well characterized. This shortfall can be addressed by leveraging off NASA programs developing technology for low-g cryogenic fluid handling.

C.1.9 Cryogenic Refrigerators. The logistics and supply requirements of cryogenic propellants can be significantly eased if active cryogenic refrigerators are developed and provided to intercept parasitic heat leaks and thus reduce propellant boil-off. Such devices are being developed in support of sensor cooling requirements. The technology necessary to re-liquify cryogenic fluids for extended periods is a subset of that being developed for sensor support, but no specific programs are supporting its implementation.

C.1.10 Sensor Replacement and Recalibration. Sensor payloads are the element of spacecraft systems most likely to fail or degrade. They are often difficult to service due to a high degree of integration and inaccessible locations. Many sensors will require recalibration during service in order to meet the long life requirements anticipated for future space assets. These calibration systems must be internal to the sensor system, and more practical than the use of a servicer vehicle. The same is true of such operations as optics cleaning. Mechanisms which bring highly integrated elements such as focal planes to the surface where they can be replaced would make on-orbit servicing of these failure-prone elements possible. The alternative is to develop interfaces and design concepts which allow replacement of the entire sensor.

Bibliography

1. Aborn, Capt Roni A. An Investigation of Non-Extravehicular Activity (NON-EVA) On-Orbit Maintenance Support Concepts for Orbiting Systems. MS thesis, AFIT/LSSR/86-83. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1983 (AD-A134957).

2. Bowman, Maj Richard L. II. "Space - The Logistics Challenge," Air Force Journal of Logistics, Vol X: 12-15 (Spring 1986).

3. Brown, Bernice B. DELPHI PROCESS: A Methodology Used for the Elicitation of Opinions of Experts, September 1968. Santa Monica CA: The RAND Corporation. (AD-675981).

4. Brynside, Major Nicholas C. Space Shuttle Integrated Logistics: Fact or Fiction?. Air Command and Staff College Report 0320-79, Maxwell AFB AL, April 1979.

5. Crossey, Major Terrence G. Lessons Learned - Complementary Expendable Launch Vehicle Acquisitions. Air Command and Staff College Report 87-0590, Maxwell AFB AL, April 1987.

6. Dalkey, Norman C. The Delphi Method: An Experimental Study of Group Opinion, June 1969. Contract F44620-67-C-0045. Santa Monica CA: The RAND Corporation. (AD-690498).

7. -----. Delphi, October 1967. Santa Monica CA: The RAND Corporation. (P-3704).

8. Department of the Air Force, Military Space Doctrine. AFM 1-6. Washington: HQ USAF, 15 October 1982

9. Emory, C. William. Business Research Methods. Homewood Illinois: Irwin Inc, 1985.

10. Gorman, Capt Frank. A Proposed Logistics Career Development Model. MS thesis, AFIT/GLM/LSM/86S-27. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1986 (AD-A174533).

11. Graham, Lt Colonel James L. Jr. "The Space Shuttle-Logistics Challenges," Air Force Journal of Logistics, 6: 23-25 (Summer 1982).

12. Graham, Lt Colonel James L. Jr. and Maj Edward J. Tavares. "Supportability: A Strategic Defense Initiative Research Imperative," Air Force Journal of Logistics, 10: 16-19 (Spring 1986).

13. Gregor, Capt Ralinda. A Normative Model of the Ideal Qualities, Characteristics, and Background of the Senior Air Force Civilian Logistician. Unpublished MS thesis, School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1988.

14. Linville, Lt Col Ray P. "Building a Logistics Roadmap for the Future." Air Force Journal of Logistics, 9: 4-7 (Winter 1985)

15. Lloyd, Lt Colonel David E. and Capt John K. Beals. "Will The Next Generation of Senior Military Logisticians Be Qualified To Manage In An Era Of Expanding Logistics Horizons?" Proceedings of the Society of Logistics Engineers, Twenty-Third Annual Symposium: 113-121, 1988.

16. Lupton, Lt Colonel (Ret) David. "Space Doctrine," Strategic Review, 11: 36-47 (Fall 1983).

17. Nancarrow, Donald W. An Investigation of the Essential Qualities, Characteristics, and Background Requirements For A Professional Senior Civilian Logistician. MS thesis AFIT/GLM/LSM/87S-49. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1987, (AD-A186980).

18. Odom, Pat R. Ph. D. "Space Logistics Challenges In The Early 21st Century," Proceedings of the Society of Logistics Engineers, Twenty-Third Annual Symposium: 337-346, 1988.

19. Overbey, Capt Allan D. A Normative Model of the Essential Qualities, Characteristics, and Background Requirements for a Professional Senior Military Logistician. MS thesis, AFIT/GLM/LSM/85S-61. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1985 (AD-A161442).

20. Pacer Frontier Program Management Plan, Sacramento Air Logistics Center, Air Force Logistics Command. Science Application International Corporation, April 1988.

21. Parente, Frederick J. and others "An Examination of Factors Contributing to Delphi Accuracy," Journal of Forecasting, 3: 173-182 (April-June 1984).

22. Reynolds, Colonel Jon F. and Lt Colonel James L. Graham. Management Implications of Support Capabilities for Space Shuttle Operations. Industrial College of the Armed Forces Report 83-013, Fort Lesley J. McNair, Washington DC, May 1983.

23. Rosen, Maj Harry W. Space Operations - Resource Management Threat To Program Designation, Air Command and Staff College Report 82-2120, Maxwell AFB AL, March 1982.

24. Rosenstein and others. "Space and the Society of Logistics Engineers," Logistics Spectrum, 15: 48 (Winter 1981).

25. Sackman, H. Delphi Assessment: Expert Opinion, Forecasting, and Group Process, April 1974. Contract F44620-73-0011. Santa Monica CA: RAND Corporation. (AD-786878).

26. Sawaya, Lt Colonel George J. "Logistics In Space Today and Tomorrow," Proceedings of the Society of Logistics Engineers, Twentieth Annual Symposium: Sawaya 1-7, 1985.

27. -----. "Logistics In Space SDI - A Year Later," Proceedings of the Society of Logistics Engineers, Twenty-First Annual Symposium: Sawaya 1 - 9, 1986.

28. Shacklett, Maj Jack L. "Down-to-Earth Space Logistics," Logistics Spectrum, 20: 39-41 (Fall 1986)

29. Taylor, Maj Edward G. Use of Commercial Management Practices to Decrease Satellite Acquisition Costs, Air Command and Staff College Report 84-2550, Maxwell AFB AL, 1984.

30. Wile, Capt David B. "Space Logistics Technology - The New Challenge," Air Force Journal of Logistics, 12:30-34 (Summer 1988).

31. Wyatt, Maj Linda S. On-Orbit Space Maintenance, Air Command and Staff College Report 87-2780, Maxwell AFB AL, April 1987.

32. Zavada, Capt Adelle R. The Senior Military Logistician: An Empirical Study of United States Air Force Colonels. MS thesis, AFIT/GLM/LSM/86S-92. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1986 (AD-A174142).

Vita

Captain Stewart G. Carr [redacted] attended the University of Texas, Arlington, from which he received the degree of Bachelor of Science in Criminal Justice in May 1979. Upon graduation, he received a commission in the USAF through the ROTC program at Texas Christian University and entered active duty in August 1979. He completed missile combat crew training in December 1979 and was assigned to the 341 Strategic Missile Wing, Malmstrom AFB Montana. In 1984, he cross trained into ICBM maintenance and was assigned to the 321 Strategic Missile Wing, Grand Forks AFB North Dakota where he served until entering the School of Systems and Logistics, Air Force Institute of Technology, in May 1988.

[redacted]

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) AFIT/GLM/LSM/89S-6	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION School of Systems and Logistics 6b. OFFICE SYMBOL (If applicable) AFIT/LSM	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Air Force Institute of Technology Wright-Patterson AFB OH 45433-6583	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
AN EXPLORATION OF ISSUES RELATED TO FUTURE SPACE LOGISTICIANS

12. PERSONAL AUTHOR(S)
Stewart G. Carr, B.S., Capt, USAF

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
MS Thesis	FROM ____ TO ____	1989 September	201

16. SUPPLEMENTARY NOTATION

17. COSATI CODES

FIELD	GROUP	SUB-GROUP
22	01	

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Space Logistics, Training, Space Logisticians, Qualifications, Space Maintenance, Future Requirements

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Thesis Advisor: Carl L. Davis
Assistant Professor of Research Methods

Approved for public release: IAW AFR 190-1.

Larry W. Emmelhainz

LARRY W. EMMELHAINZ, Lt Col, USAF 14 Oct 89
Director of Research and Consultation
Air Force Institute of Technology (AU)
Wright-Patterson AFB OH 45433-6583

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL Carl L. Davis, Capt, USAF	22b. TELEPHONE (Include Area Code) (513) 255-2254 / 22c. OFFICE SYMBOL AFIT/LSR

DD Form 1473, JUN 86 Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

Abstract

The purpose of this research was to explore the space logistics arena for issues related to space logistician development, that require further research. The study specifically looked at qualifications, training, maintenance, and future requirements to determine areas that may require advanced preparation in the development of future logisticians.

The study found that there are no specific qualifications peculiar to space logistics. Experience and an understanding of the space environment were seen as the most desirable qualities. However, the personnel system does not allow the space logistician to gain enough experience before they are moved, and the lack of training for new space logisticians severely hampers their usefulness.

The future requirements for space logisticians is increasing. The Air Force role in space is projected to increase significantly over the next decade and a space logistics infrastructure needs to be developed now if the Air Force is to meet its own needs. Such issues as organic launch capability and on-orbit maintenance and support are serious future requirements for the Air Force.

This study found ten such issues that require further refinement before the findings of this research can be generalized outside the bounds of this thesis. Care should be taken to ensure these findings are not misguided.